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THE DEVELOPMENT AND PRESENTATION OF FOUR COLLEGE COURSES BY
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THIS IS A FINAL REPORT ON THE DEVELOPMENT AND PRESENTATION OF FOUR COLLEGE COURSES BY COMPUTER TELEPROCESSING FROM APRIL 1964 TO JUNE 1967. IT OUTLINES THE PROGRESS MADE TOWARDS THE PREPARATION, DEVELOPMENT, AND EVALUATION OF MATERIALS FOR COMPUTER PRESENTATION OF COURSES IN AUDIOLOGY, MANAGEMENT ACCOUNTING, ENGINEERING ECONOMICS, AND MODERN MATHEMATICS. EQUIPMENT CONFIGURATION IS DESCRIBED, AND A DIGEST OF THE COURSEWRITER LANGUAGE, PROGRAM SAMPLES, AND OUTLINES OF MATERIALS USED FOR THE FINAL PRESENTATION ARE INCLUDED. DATA ON STUDENT REACTIONS AND PERFORMANCES ARE REPORTED. (MS)

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COMPUTER ASSISTED INSTRUCTION LABORATORY

COLLEGE OF EDUCATION · CHAMBERS BUILDING
THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.

FINAL REPORT

Contract No. O. E. 4-16-010
New Project No. 5-1194

THE DEVELOPMENT AND PRESENTATION OF FOUR COLLEGE COURSES BY COMPUTER TELEPROCESSING

June 30, 1967

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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THE DEVELOPMENT AND PRESENTATION OF FOUR COLLEGE COURSES BY COMPUTER TELEPROCESSING

Contract No. O. E. 4-16-010
New Project No. 5-1194

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CHAPTER I

INTRODUCTION

Americans are bombarded almost daily by books, magazines, newspapers, television, and radio on the subject of the impending crisis in extending our educational resources to cope with expanding and changing education and technology. The crisis and its special implications for higher education have been documented by the American Council on Education (Venn, 1964). The curriculum development, research, and dissemination activities undertaken in the present project represented an exploration of one technological advancement which holds promise for alleviating a portion of this educational crisis.

Our total educational effort in the United States is faced with a number of major challenges. One of these comes from the school population explosion at all educational levels, which has resulted in a nationwide shortage of teachers and instructional facilities. The indications are that this inadequacy is likely to persist for some years. However, the problem is more difficult than the mere expansion of present educational effort. A major problem is associated with the change in the job that schools and colleges are being asked to perform for society; changes in the society itself, which educational institutions serve, are increasingly dramatic and complex. The situation may be summarized by saying that at a time when all facets of the educational enterprise are increasing at the greatest rate in all history, it is at the same time expanding the breadth, the depth, and the scope of education.

In attacking the problems of education, the first encountered difficulty is that the total resources available for educational development are quite limited relative to the magnitude of the task to be undertaken. Thus, it is necessary to accept progress toward these goals as less than would be desired under ideal conditions, and to recognize priorities of greatest importance as primary tasks. The difficulties go well beyond the mere resource allotment in a monetary sense. In order to get a feeling for the extent to which this is true, it is well to consider the nature of ideals which are becoming generally accepted for future public education in this country: 1) the length and scope of education freely available to each person in the entire population are to be extended as soon as feasible to encompass all of the education that will benefit a person;[1] 2) no significant fraction of the population should receive an education which can be regarded as being of poor quality; 3) education is a major process continuing throughout the life of the individual.

If one considers these ideals as goals, it becomes apparent that there are greater impediments to attaining some of them than the difficulty of obtaining the very substantial economic resources required. As a nation we can no longer afford the luxury of merely trying to do more of what we have been doing in the past. Thus, the decision to increase significantly the content of education at all levels has very far-reaching implications for the in-service education of teachers.

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[1] Cf. Policy Statement on education issued by President Johnson on November 4, 1964. ". . . every child has the right to as much education as he has the ability to receive. I believe that this right does not end in the lower schools, but goes on through technical and higher education, if the child wants it and can use it . . . ."

Perhaps the greatest difficulties of all do not arise directly from the requirements being placed on educational institutions, but stem from changes in the character of society itself. Surely, the most important single socio-economic phenomenon of the present era is the rapid shift from an economy based on limited-skill labor to one which rests on intelligent personal service of an increasingly technical nature. Moreover, at a time when jobs are becoming increasingly technical, it is also true that the technical competence required of workers is changing at an accelerating rate. In many vocational and professional areas today, the rapidity of technical and scientific advance has become so great that it is literally impossible to create academic curricula which are not obsolete at the time of their inception.

In a sense, the problem of the rapid obsolescence of curricula arises whenever the period of significant technological change is comparable to, or shorter than, the period required to train the majority of those who must teach the material. The accelerating pace of technological development implies that such conditions are going to become more and more general until they impact education across the board. It follows then that the methodology of education, the concepts of teacher education, and the general structure of education must undergo significant and drastic changes in the near future. Indeed, the greatly increased educational requirements, the correspondingly longer training periods needed to attain a given level of proficiency, and the ever-changing character of subject matter already are imposing great burdens on existing efforts in education and are creating an impetus for change in the methodology and structure of instructional processes.

Clearly, new methodologies and techniques of education are of great importance where they seem capable of overcoming these fundamental difficulties. The technical approach which has been the focus of this investigation may be described as computer-assisted, teacher-supervised, self-study, and hereafter referred to as computer-assisted instruction (CAI). There were a number of reasons to suggest that this approach might be fruitful: 1) potentially, it permits an efficient use of expensively and highly educated teachers, and thus a substantial increase in the student-to-teacher ratio; and 2) at the same time, it makes possible an acceleration and individualization of instruction to an extent which has often been dreamed in theory, but rarely achieved in educational practice.

Specifically, the objectives of the project were as follows:

1. To determine the feasibility of using college teachers with limited knowledge of digital computer systems and computer

programming to prepare various subject matters for presentation by a computer. The teachers were aided in the preparation of these materials by the use of a special computer language developed especially for teacher-authors. This language, known as Coursewriter, allows an author to program the computer to present materials on the basis of the students' responses by the use of a number of logical commands. One purpose of the project was to suggest improvements in the author language on the basis of actual author experiences. An anticipated outcome of the project was a more efficient special computer language for course writing by teachers. In addition, the feasibility of teaching several different subjects simultaneously by means of the computer was an important part of this objective.

2. A second objective was to ascertain the reactions of students to the course materials presented by a computer. Authors were encouraged to try out alternative teaching strategies in CAI so that preliminary evidence could be obtained to determine which methods of presentation would be most acceptable to the student. A preliminary evaluation of student responses to computer-assisted instruction, using sections of courses instead of full-length courses, and which involved 67 college students was made; these data are reported in Chapter VIII. During the spring term and summer term, 1966, at Penn State, field trials were then conducted for each of four college courses.

3. A third objective was to make comparisons of the effectiveness of computer presentation of course materials with the

lecture-discussion method. No systematic comparisons of CAI and conventional lecture presentation were made; however, some informal comparisons were undertaken to help evaluate the quality of the CAI materials. The investigators associated with this project question the value of comparing teaching methods. Rather than attempting to "reject the null hypothesis" with regard to comparisons of CAI with traditional instruction, it was expected that such comparisons would help improve existing course materials and help identify a rationale for integrating sections of CAI courses with existing curricula. If CAI is to be an important educational medium in the future, the situations in which its use is most desirable and the methods for best integrating it into the general educational process must be quickly identified. The experiences of the teacher-authors reported in a later section of this report bear on the above question.

4. A fourth objective was to provide demonstrations of a functioning prototype of a computer-assisted instructional system which could be expanded to provide service to an entire school or group of schools. Dissemination of information is a serious problem in educational research. By means of live "hands on" demonstrations, video tape recordings of students working with CAI, and a short introductory color film the investigators hoped to make some inroads into the problem of dissemination.

5. A fifth objective of the project was to determine the feasibility of a computer-assisted instructional system in which course material and student responses are teleprocessed over

some distance between teaching terminals and a centrally located computer. While the chief purpose in teleprocessing in the present project was to eliminate the need for an expensive computer system and programming support, there are educational situations in which remote instructional terminals might be the most desirable feature of a CAI system. One such application would be a continuing education program, such as updating the training of graduate engineers. Another application is the in-service education of public school teachers.

6. The sixth and final objective was to develop CAI curricula of sufficiently high quality to be used in later research studies with actual college and high school students. While the primary purposes of the investigation were the five listed above, CAI offers many opportunities for research on problems of complex human learning and instruction. A computer-controlled instruction system offers opportunities for carefully manipulated presentation of verbal and visual stimuli (instructional materials) rarely possible in previous research on instruction. The courses were developed in such a manner that they are readily amenable to experimental manipulations and research on student learning. A number of investigations have been proposed, and the results of several pilot investigations are reported in Chapter VIII of this report.

CHAPTER II

DESCRIPTION OF THE COMPUTER-ASSISTED INSTRUCTIONAL SYSTEM AND RELATED LITERATURE[1]

Computer-assisted instruction may be thought of as a way to enhance the effectiveness of teachers and the teaching process through technology. In the past, devices such as motion pictures, filmstrips, workbooks, and language laboratories have been incorporated into educational practice to facilitate and extend learning; generally, these devices have been used to automate traditional methods of teaching and not necessarily to make learning more functional. Regardless of the device, the general approach here has been to maintain the traditional method of teacher-mediated group instruction in the more or less conventional classroom situation. The conception of CAI which has guided our work has been to supplement rather than supplant the teacher in the classroom.

The publication of Skinner's Science paper in 1954 set forth an alternative approach to the achievement of educational goals. Programed instruction specified desirable terminal behaviors and used the principles of a learning theory to establish a means of attaining these behaviors. The instructional sequences in Skinner's plan were individualized in linear programs through self-pacing, or more recently in branching programs through the formulation of different sequences on the basis of a student's last response. Early in the movement, machines were fabricated to present these programed materials; however, it was found in most cases that the use of hardware did not enhance learning over the use of the same materials in text form (Goldstein & Gotkin, 1962).

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[1] The investigators are indebted to Dr. E. N. Adams for the basic analysis of the field as contained in this chapter.

Research and development involving the use of a computer to assist in the instructional process may be thought of as being related to teaching machine technology; but, CAI, because of its flexibility, decision logic characteristics, and sophistication of input-output modes, must be considered as a quantum advance (at least in theory) over traditional programed instruction. Projects using a computer for instruction are similar to each other but differ in their emphasis. The flexibility of the digital computer allows for a variety of themes different from and richer than the themes of programed instruction as represented in the programed text or simple teaching machine. One such theme has been the use of sophisticated input and output displays to facilitate communication between the student and the system, e.g., cathode ray tube display, various large capacity random-access visual and audio devices, special response keyboards, and light pens. These devices are particularly attractive to the psychologist interested in research, but at the same time do not stimulate similar research in other laboratories because the equipment used is generally of experimental or prototype construction and is extremely expensive. Two efforts that emphasize this theme in computer teaching are those of Bitzer (1962, 1964) and Suppes (1964).

A second theme has been to adapt course organization to the individual student's needs. Here the concept is to monitor and analyze student performance; and, on the basis of this performance plus other historical information about the individual student, continually adjust the course organization to optimize it for a particular student's progress. Such tailoring of materials to an individual student is highly desirable but of relative high cost because considerable computer capability is needed for each student. To some extent, this has been the approach taken by Stolurow (1963) and Smallwood (1962).

A third theme has been that of tutorial interaction. The concept here is that the high-speed logic of the computing machine reacts to the detailed features of student performance on specific tasks, records the efforts of the student in dealing with these tasks, and presents appropriate remedial or accelerated action where the student is not succeeding or is insufficiently challenged. The tutorial interaction is supplementary to the strategic job of adjusting the arrangement and difficulty of the tasks and their manner of presentation to the individual student. This approach was exemplified by the early effort at the IBM Research Center (Uttal, 1961, 1962), and has been characteristic of the CAI curriculum materials developed at Penn State, Florida State, University of California at Irvine, and other pioneering institutions.

A fourth theme has been the process of simulation and gaming interaction between the student and the machine. Here the role of the machine is that of simulator of a process or as an opponent with which the student interacts just as he interacts with process or persons in laboratories or real situations. This theme is prominent in the work at Bolt, Beranek and Newman, Inc., (Swets, 1962) and Wing (1966) at the Board of Cooperative Educational Services, Westchester County (N. Y.) Public Schools.

In addition to the above studies, the reader may find the reviews by Dick (1965) and Gentile (1966) helpful in providing additional background in the development and status of computer-assisted instruction.

The present investigation of computer-assisted instruction emphasized tutorial interaction and made limited usage of the other themes described. The writers believe that each of the emphases described above represents a valid conception of an approach to the use of computers as educational aids, but that the tutorial approach may be practical for many instructional purposes. Current and projected needs forced the investigators to consider computer instructional cost, both for the development of courses and the administration of these courses by the computer in "production" teaching. The investigation sought to establish a flexible interface between the learner and the computer, but at the same time to utilize a system that would be justifiably economical in the long run to allow for wide-scale adaptation to a variety of educational operations.

Because of the high cost of computer systems for direct teaching, a number of educational developers have turned to the employment of the computer as an aid in the management of instruction. Under this concept, each school or instructional sub-unit is provided with a terminal connected to a central computer. Input consists of information about each pupil's progress on separate identifiable elements of "off-line" curriculum material. Output at the terminal consists of a set of diagnostic instructions directed to the teacher for managing the education of each child. This new "systems" approach or computer-management instructions bears the same relationship to CAI that remote batch processing bears to time-shared conversational interaction in conventional computer terminology. It remains to be seen which approach will be the most readily accepted by the education community.

The main outcome of the present project was the development of four college courses for presentation via CAI. Unlike most developmental projects in CAI, the present project was not concerned with the invention of terminal hardware or the writing of computer programs in machine language. These tasks have been avoided by using a commercially available typewriter terminal as the interface between the computer and the student, and the Coursewriter language (Appendix A.1) developed at the IBM Thomas J. Watson Research Center for controlling this interchange. Virtually all of the efforts of the project have been devoted to the preparation of educational materials to be presented by a computer.

The Coursewriter language enables an author, with a minimum of special training, to include questions, problems, assignments, correct answers, incorrect answers, provisions for unanticipated answers, knowledge of results, and branches or alterations in the sequence of a course. In addition, an author can employ a process of record keeping known as Student Records, which will record and accumulate in storage all student responses and response times. This latter feature is useful to authors for the purpose of analyzing and improving the course content, for revising trial versions of a course, and as a basis for counseling and advising students who use the course material. Additional operations in Coursewriter can call for the presentation of visual material stored on 2 x 2-inch slides or audio material stored on magnetic tape at the student's terminal. This presentation is mediated by a computer-controlled random-access slide projector and random-access tape recorder. During the development of course materials, new functions were periodically added to Coursewriter which were then implemented into each course. Among these additions, for example, were functions which allow flexibility in matching stored answers, i.e., functions which command the computer to ignore trivial characters such as commas, periods, spaces, differences in word order, and misspelling if desired. A more detailed description of the operation codes used with the Coursewriter language is given in Appendix A.1.

The computer system employed in the early phases of this investigation was an IBM 7010 (compatible with the IBM 1410), with remote IBM 1050 typewriter terminals. The main computer was located at the IBM Thomas J. Watson Research Center in Yorktown Heights, N. Y., while the typewriter terminals were located in Chambers Building on the campus of The Pennsylvania State University. In March, 1966, computer service was initiated from the Penn State Computation Center to service two terminals for CAI. Dataphones and telephone lines were used for transmitting information between the Chambers Building terminals and the central computer. The student terminal configuration was an IBM 1050 instructional terminal which included a modified IBM Selectric typewriter and which permitted two-way communication between a student in Chambers Building and the computer at Yorktown Heights (or more recently the IBM 1410 at Penn State's Computation Center); a random-access slide projector; and a random-access tape recorder -- all components under computer control and activated by a set of instructions stored in the central processor. Course material can be presented to a student by typeouts, slides, or tape recordings. In answering a question or problem, the student types his answer at the terminal and relays it to the central computer. The computer then provides knowledge of results to the student, remedial information, or the next problem.

In addition to the student instruction mode, the typewriter terminal can also be used in "author mode" for input of course material, revision of course material, or for author testing of course material. The course input is transmitted to the computer where it is stored on high-speed magnetic discs to which the computer has selective access to any part. In addition to "on-line" input of course materials, the use of an IBM 1058 card punch attached to a typewriter terminal permits off-line Coursewriting on IBM cards. The cards can then be transferred to the central computer and input for disc or tape storage. The latter procedure frees more on-line terminal time for student instruction.

CHAPTER III

PREPARING COURSES FOR COMPUTER PRESENTATION

As previously mentioned, courses have been prepared for presentation via computer by means of a language known as Coursewriter. Although a complete description of the language is beyond the scope of this report, a summary of the functions of each of the operation codes is given in Appendix A.1. A manual emphasizing the application of Coursewriter language to instructional strategies is in preparation as an extension of the current Penn State program.

The list of operation codes taken from the IBM Coursewriter manual (1965), although not exhaustive, covers most of the basic operations in the language. A reproduction of a course as it is stored in the computer is shown in Fig. 1. Each operation code has an accompanying sequence number which is used to identify and sequence the course material. In preparing a program for the computer, the author prefaces segments of the course with the appropriate operation codes. The operation code indicates to the computer how the argument of that operation code is to be used. For example, the entry for a question consists of a qu followed by the text (argument). The qu code instructs the computer to type the question (argument) on the terminal and to wait for the student to respond.

Sequence No.	Label	Op Code	Argument
aa-0010-010	intro	qu	3 + 2 =
aa-0010-020		ca	5
aa-0010-030		ty	correct
aa-0010-040		wa	6
aa-0010-050		ty	You multiplied instead of adding. Try again.

Fig. 1. Reproduction of a Typical CAI Course Segment

The amount of material stored for any given sequence number (usually referred to as a "statement") is dependent upon the operation code used. There is no limit to the amount of material which can be stored in the argument of a rd, qu, ty, or un statement. If the statement is a ca, cb, wa, or wb, the argument is limited to 99 characters. Any letter, space, upshift, downshift, or any other single-key operation on the typewriter terminal is counted as one character.

The label is an identifiable name selected by an author for any statement in a course. The label provides a meaningful symbol which can be branched to by using a br statement.

One major objective of the present project was to test the feasibility of having college faculty members with minimal computer experience prepare courses for computer-assisted instruction. College level courses were prepared in four subject matter areas: audiology, modern mathematics, management accounting, and engineering economics. Table 3.1 provides a summary of the course materials completed in the four course areas as of December 31, 1966. The values in this table represent the final content of the course and include no indication of the number of statements revised or rewritten.

Table 3.1

Summary of CAI Programs Completed
for Four College Courses
December 31, 1966

Course	No. of Coursewriter Statements	No. of Slides	No. of Tape Recorded Messages	No. of Static Displays
Audiology	8,145	197	127	33
Management Accounting	6,556	67	34	23
Modern Mathematics	11,765	258	138	--
Engineering Economics	4,104	5	7	61
TOTAL	30,570	527	306	117

Considerable variability exists in the programing strategies used by the authors. This variability seems to be a function of differences in course content, the ease of programing different courses for the computer, and the authors' teaching preferences. One author used primarily an inductive approach in which examples and problems are illustrated followed by questions designed to help the student discover the principle involved. Several authors employed a large number of branches to remedial or explanatory material, while others presented explanatory material in the main trunk of their program. Some authors used a liberal number of prompts or hints to elicit student responses, while others required the student to do more independent searching for correct answers. Differences also exist in the kinds of questions that have been used (multiple choice, single word completion, true-false, multiple word constructed response) and in the quantity and quality of knowledge of results, feedback, and reinforcement. These "built in" differences among and within courses have provided useful materials for future experimental tests of the effectiveness of the different methods of presentation.

Our experience with programing different courses suggests that although most subject matters can be taught feasibly via CAI, some are especially well suited for computer-assisted instruction. For example, the presentation of visual and auditory materials via the slide projector and tape recorder would seem to be particularly effective when they provide nonredundant information to the learner. Simply presenting material on slides and tapes which can be presented as well by a printed display to the student holds no great advantage for learning other than whatever advantages accrue from repeating the communication in the different sensory modalities. In many courses, however, information can be conveyed by slides and/or tape recordings which would be difficult to transmit to the learner by other means. Slides were developed for the audiology course which portray various parts of the human auditory system. The slides were developed in a manner similar to overlays for overhead projection -- emphasizing one section at a time until an entire anatomical system is displayed. Another particularly interesting use of the tape recorder was used in the audiology course. Correct pronunciation of anatomical terms were played for the students whose job it was to learn proper pronunciation of a difficult vocabulary as well as correct anatomical location.

Training CAI Course Authors

The present project was one of the first to implement the preparation of course materials for CAI using the Coursewriter language and teleprocessing from remote terminals. For this reason, problems were encountered early in the project which can now be avoided in future CAI projects. Although several short training workshops were held for the project staff by IBM personnel, it is fair to say that most of the project staff were largely self-taught. It is hoped that our early experience with CAI will be of some help to other investigators who plan to do work in this area.

Although Coursewriter is a relatively simple language to use when compared to other more traditional computer languages such as Fortran, Daft, Algol, and Autocoder, considerable time was spent during the first few months of the project learning to use the language. In the judgment of the investigators, training authors in a more systematic fashion by means of a two- or three-week workshop to provide supervised coursewriting experience would be superior to the trial-and-error training necessitated in the present project. The training of authors in the early stages of the project was hampered by several problems: 1) the CAI hardware itself had only been recently installed and debugging was being completed; 2) the Coursewriter language was in the process of being written and revised, and thus was changing from week to week; and 3) authors were faced with the more difficult problem of fully utilizing the instructional potential of CAI. As more experience was gained with computer-assisted teaching systems, problems of author training were minimized.

Aside from learning the Coursewriter operations, the most difficult problem facing a potential author of courses in CAI is that of utilizing the dynamic properties of CAI. Preparing materials for CAI is very different from preparing materials for a traditional lecture class of 40 or 50 students. Most traditional lectures, like earlier forms of programed instruction, involve linear teaching strategies. To conceive and develop a course,which will adapt to the abilities and interests of any learner in a population of learners exhibiting wide individual differences, requires skills which have frequently not been acquired by many teachers or professors, nor have they often been taught in teacher education curriculums. The most likely reason for the neglect of these skills for individualizing instruction is the great complexity which they introduce into the design of teaching strategies and instructional materials.

Within the domain of adaptive CAI, one can conceive of multiple track and hierarchical instructional strategies. A number of the authors developed flow charts of their courses prior to the actual production of the course. Flow charting has the advantage of forcing an author to state his objectives prior to course development, and to graphically indicate various routes through the course by which students of different abilities and interests can reach the course objectives.

The use of adaptive CAI also involves some assumptions about the nature of student learning which are frequently either unaccepted or ignored in traditional teaching situations. The use of adaptive teaching systems assumes that the variability in attainment of learning objectives among different learners can be substantially reduced. Although some psychologists find evidence for a genetic limit in a student's learning ability, recent evidence points to the great malleability of such variables as measured intelligence and school learning. One of the most striking early findings of the present investigation (more fully reported in Chapter VIII) was the great spread of criterion test performance among college students on CAI courses specifically designed to include remedial work and adaptation to individual differences. In one section of modern mathematics containing approximately fifty per cent remedial work given to students having difficulty in the main course, criterion achievement test scores ranged from 5 to 23 on a 23 item test. The reader should note that these were a select sample of college students having generally high mean academic aptitude test scores and short range. Such widespread variability in achievement found among these students can only stem from a failure of the instructional strategy. One of the most valuable attributes of computer-assisted instruction for training instructional programers is the ease with which authors obtain feedback concerning the adequacy of their courses. In the normal classroom situation, feedback concerning one's teaching procedures is frequently delayed too long for the feedback to be relevant. In CAI, feedback concerning one's course can be obtained almost immediately by signing on as an author-student to test the course. Rarely does the classroom teacher have an opportunity to "sit in the student's shoes"; however, such experience is the rule rather than the exception in CAI. In addition to having firsthand experience as a student on one's own course, information concerning the performance of regular students is readily available. Such students have been used to provide information to help diagnose the strengths and weaknesses of a course.

Capabilities for rapid revision are required of an instructional system if feedback concerning the adequacy of instruction is to lead to improvements in the course. One of the major advantages of CAI is its potential for rapid revision of course materials. Depending on previous scheduling of computer time, revisions can be made within several days. This is a particularly important characteristic since the preparation of course material frequently requires considerable revision to smooth out minor defects.

Preliminary results concerning the incidence of mechanical malfunctions with the basic typewriter input-output terminal have been highly encouraging, especially in view of the complex electronic system involved. One objective of the project was to test the feasibility of teleprocessing course material to remote instructional terminals. A check of a sample of 10,374 statements of program completed by a small sample of students showed that transmission errors occurred in only 0.2 per cent of the statements. On the basis of these preliminary results, we can conclude with some certainty that computer-assisted instruction at remote terminals via teleprocessing is surprisingly free of mechanical malfunctions.

Field Trial

One of the major results of the project was the development of four operating CAI courses. During the spring term of 1966, a field study was conducted using three of the courses - Speech Pathology and Audiology, Introductory Management Accounting, and Modern Mathematics. Engineering Economics was field tested during the summer term of 1966 at Penn State University.

In order to provide the students with the best educational experience possible, a general methodology was used for all of the field trials even though there were minor variations within each course. Each of the courses was a three-credit course which normally meets three periods (75 minutes each) a week for 10 consecutive weeks. Each class participating in the field trial was divided into three groups. Group 1 was in attendance at all class meetings with the professor; this group was identified as the lecture group. Group 2 was in attendance at one class meeting at the beginning of the week; two class meetings (equivalent time) were spent at the teaching terminal in the CAI Laboratory. This group was identified as the CAI group. Group 3 was in attendance at one class meeting at the beginning of the week; and two class meetings (equivalent time) were spent in the Curriculum Materials Center in the College of Education. This group was identified as the self-study group.

CAI Group. The CAI Laboratory Staff scheduled students according to time available on terminals and individual schedules for no less than a total of two and one-half hours per week. Students could, of course, spend more or less time as required by their work habits and assignments. The Laboratory staff provided such materials as handouts, models, reference books, colored pencils, slides, and tapes necessary for the students to use as they progressed through the course. A proctor from the staff of the Laboratory was available at all times when students were scheduled on terminal. The professor of each course was provided with a carbon copy of each student's printout from the terminal, and the student retained one copy for review purposes.

Self-Study Group. Students were scheduled at the Curriculum Materials Center for two and one-half hours per week according to their individual schedules. The Curriculum Materials Center is a library-type facility equipped with individual study carrels where specific references may be placed for student use. Materials such as handouts, models, reference books, sets of slides, and slide projectors were provided in the Curriculum Materials Center for the students' use. A proctor was available at all scheduled times to distribute materials as requested by the students, and to record the amount of time spent by each student using self-study materials.

Chapters four, five, six and seven of this report present the details of the course development and field study for each of the four courses developed for CAI.

CHAPTER IV

INTRODUCTION TO AUDIOLOGY

(Bruce M. Siegenthaler and Jeffrey Katzer--Course Authors)

"Introduction to Audiology" (Speech Pathology and Audiology 430, 3 credits) is the first course in audiology at Penn State and is normally taken during the junior year of undergraduate study.

The objectives of this course include the following:

1. Introductory survey of the field of audiology;
2. Development of a knowledge of technical terms used in audiology;
3. Classification of information regarding the anatomy and physiology of the normal ear and of ear diseases at a survey level;
4. Understanding of general principles of testing hearing and development of skill in administering pure tone air conduction tests and their interpretation;
5. Survey of rehabilitation measures for hearing handicapped.

Although the course is required during the junior year of the undergraduate SPA (Speech Pathology and Audiology) curriculum and the major enrollment is by these students, the course is also taken by a number of graduate students in the master's program in SPA and by students from outside SPA who minor in this field.

During the winter term, 1965, a small-scale evaluation of CAI as applied to SPA 430 was completed. Of the 25 students enrolled in the class, 12 volunteered to participate in CAI as a supplement to class attendance. These 12 volunteers were randomly divided into two groups, one to receive CAI and the other not. All students other than the 12 volunteers attended three lectures each week. However, six CAI students spent time on the computer terminal to complete the material on anatomy and physiology of the ear. At the end of the first third of the course (when the work on anatomy and physiology was completed), a comprehensive test on that material was administered to all students. These data were analyzed for the three groups: 1) students who had not volunteered for CAI, 2) students who volunteered for CAI but who were included by the random process, and 3) students who volunteered for CAI and were selected. For Group 3, a comparison was also made of those questions supplemented by CAI and those questions not supplemented by CAI.

The results, based upon a very small sample as cited above, did not indicate a clear-cut advantage for the students receiving CAI either for the CAI-related questions or for the non-CAI related questions. However, it must be remembered that all students attended all lecture sessions and therefore all received the same instruction via lectures.

Subjective evaluations of the computer program by students were highly enthusiastic. Some of them were able to complete all of the program material in as little as two hours of terminal time, while others required about six hours. Those who experienced CAI felt they had benefited by the instruction (although their scores did not clearly indicate this), and all of them expressed a high level of interest and motivation to continue with additional CAI activities.

Field Trial

A field trial of the CAI speech pathology and audiology course was conducted during the spring term, 1966. The purposes of this study were twofold: 1) to investigate the problems involved with providing CAI experience for a number of students on a regular basis for academic credit, and 2) to obtain and analyze data for improving the CAI course based on student responses and reactions.

Random Assignment of Students. The 21 students who enrolled in the speech pathology and audiology course were stratified into three levels on the basis of Scholastic Aptitude Test scores. The students in each of the stratified groups were then randomly assigned to one of the field study conditions - self-study, CAI, or lecture.

Lecture Group. The seven students assigned to the lecture group met with the professor three periods (75 minutes each) weekly. This segment of the class group was taught according to the standard procedures used by the professor for a lecture-discussion class.

Self-Study Group. Seven students were assigned to the self-study group. These students met in the lecture group one period each week with the professor and were assigned to the Curriculum Materials Center, located in the College of Education, for two periods each week. Appendix D.1 includes a sample of the self-study guides available to each student. Appendix D.2 is a list of the anatomical slides which were also available with a projector in the Curriculum Materials Center for the students to use. Table 4.1 indicates the amount of time spent in the Curriculum Materials Center by each student who was assigned to the self-study group. The students were not informed that a record was being made of the amount of time they spent in the Center, nor was this time used to evaluate students in any way. It merely indicates that some students spent considerably more time using the specific references placed in the Center.

CAI Group. Seven students were assigned to the CAI group. These students met with the professor and the other two groups one period each week and were assigned time on the CAI terminal for approximately two periods each week. Appendix D.3 contains a sample of the speech pathology and audiology CAI program which includes slide and tape recorded messages. Appendix D.4 is a flow chart and interpretive notes for the first part of the program. Appendix D.5 contains samples of the static displays, and Appendix D.6 contains samples of the student handouts prepared for use with the course.

Table 4.1

Time Spent in Curriculum Materials Center by Students in the Speech Pathology and Audiology Self-Study Group

Field Trial, Spring 1966

Student	Week 1	Week 2	Week 3	Week 4	Total	Average Hours/Week
1	2:55	3:25	2:45	2:30	11:35	2:54
2	2:55	2:55	3:45	1:25	11:00	2:45
3	1:30	2:15	1:55	1:30	7:10	1:48
4	1:20	2:05	1:25	1:45	6:35	1:39
5	1:40	2:25	1:55	1:40	7:40	1:55
6	1:30	1:15	0	2:40	5:25	1:21
7	2:50	2:20	3:20	2:10	10:40	2:40

Table 4.2 shows the structure and amount of course material stored in the computer. The course is segmented into chapters for ease of handling at the Computation Center; however, a student taking the course continues directly from one chapter to the next if he so desires.

Table 4.2

Structure of CAI Speech Pathology
and Audiology Course
as of December 1966

Chapters	No. of Coursewriter Instructions	No. of Questions	No. of Slides	No. of Tape Recorded Messages	No. of Static Displays
1	1932	107	25	47	3
2	841	57	9	11	4
3	464	18	6	13	2
4	910	56	15	14	4
5	593	27	23	11	5
6	440	16	17	23	1
7	325	8	17	1	1
8	402	8	13	1	2
9	517	26	6	1	1
10	413	17	7	1	2
11	555	26	11	1	4
12	362	11	12	1	2
13	391	10	36	2	2
Total	8145	387	197	127	33

Table 4.3 shows the time spent on computer terminal by the students in the speech pathology and audiology CAI group.

Table 4.3

Time Spent on Instructional Computer Terminal by Students in the Speech Pathology and Audiology CAI Group

Field Trial, Spring 1966

Student Number	Dates Beginning-Ending 1966	Time Hours-Minutes		Average Hours/Week[a] Hours-Minutes	
7577	4/25 - 5/23	17	50	3	34
7579	4/25 - 5/11	14	45	2	57
7580	4/25 - 5/19	11	49	2	27
7581	4/27 - 5/24	19	24	3	53

Total Time - 63 hours and 48 minutes

Average time per student - 15 hours and 57 minutes

[a] Calculated on the basis of maximum number of weeks (five) on terminal by student from the group.

Table 4.4 shows the character and operand code count for five representative selected questions from the course. On the basis of the information from these five questions, it is estimated that for the 387 questions and related instructions in the course there are approximately 546,300 characters in computer storage for the 13 chapters.

The entire question frame for each of the sample questions is presented on the following pages. Following each question is

Table 4.4

Character and Operand Code Count for Five Selected Questions from CAI Speech Pathology and Audiology Course

Op Codes	Ques. 1		Ques. 2		Ques. 3		Ques. 4		Ques. 5		Total f for 5 Qu's	Total C for 5 Qu's
	f*	C**	f	C	f	C	f	C	f	C		
Primary												
qu	1	169	1	125	1	158	1	92	1	118	5	662
Major												
ca	1	28	1	29	1	53	1	24	1	26	5	160
cb												
wa					3	107	1	23			4	130
un	1	177	3	208	3	331	2	72	2	183	11	971
nx	2	32	2	21	4	64	2	32	1	16	11	165
Minor												
ty	1	465	2	44	6	852	2	49	6	782	17	2192
fn	1	22	2	43	6	137	2	51	3	85	14	338
TOTAL	7	893	11	470	24	1702	11	343	14	1210	67	4618

*frequency
**Number of characters

an explanation of the functions within the question and a table which includes an exact reproduction of all responses made by each student and the response latency for each trial. This information was obtained from student record analyses from the computer and is representative of one of the benefits that an author can derive from the computer in revising and updating course material.

Sample Question 1--Speech Pathology and Audiology

Sequence No.	Label	Op Code	Argument
aa-0130-470		qu	*1.39.** Completion: The other part of the inner ear having to do with balance is, according to Newby, called the _____.
		nx	
		fn	kw//1
		ca	// vestibul
		ty	Correct. Please realize that Newby is describing the whole functioning balance part with its contents. Strictly speaking, in terms of the geography (not function), this part of the inner ear may be subdivided into two types of areas: (a) vestibule and (b) semicircular canals. For the moment it is important to remember that these are parts of the bony labyrinth-your class lecture will develop this further.
		nx	
		ad	-1//cl
		un	Wrong. Check Newby page 21, the fourth complete paragraph from the top. Look for the name of the major part--not the sub-parts. Try again.

---

*N.B. Material in italics indicates this will appear in red on printout.

Sample Question 1. This is a completion question. The student is expected to fill in the blank after referring to the textbook. The authors are expecting only one correct answer (ca), i.e., vestibul. If the student makes this response, he receives a typeout (ty) which says "correct" and gives him information about some additional material he will study. If the student does not make this correct response, -1 is added to counter 1 and he is given the feedback for an unanticipated (un) answer. He is told at this point that he is wrong and should check the textbook and try again. The information from student records presented in Table 4.5 indicates that four of the six students did respond correctly on the first trial. Those who did not, made spelling errors. It should be pointed out that none of the students responded with the precise response that the authors specified, i.e., "vestibul." The correct response programed by the authors contains the essential portion of the complete correct answer and allows for deviations of word endings that the authors were willing to accept as correct. The students could respond with the entire word, vestibul or vestibule or vestibular, plus the word "apparatus" without being counted incorrect. This indicates the flexibility that authors can provide for accepting different forms of the same correct answer and not forcing the student to match precisely character for character any one given answer. This flexibility is provided by the keyword (kw) function which appears just prior to the correct answer (ca) in the program.

Table 4.5

Student Responses and Response Latencies for Sample Question 1 from CAI Speech Pathology and Audiology Course

Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]
7577	vestibular apparatus	9.1		
7578	vestibular apparatus	13.1		
7579	vestibular apparatus	31.4		
7580	vastibular apparatus	107.6	vestibular apparatus	33.3
7581	vestibular apparatus	12.9		
7582	vastibular apparatus	13.5	vestibular apparatus	24.8

[a] In seconds

ANATOMICAL TERMS

These are terms that you should learn how to use and spell correctly. You already know many of them or you could easily guess their meanings. The procedure will be to have the computer lead you through the writing of the words in pairs. Consider the word pairs as synonyms, antonyms, or words which are used together. When you are ready to proceed, press: EOB

Write the "paired word" below.

1. distal ______________________
2. deep ______________________
3. posterior ______________________
4. inferior ______________________
5. anterior ______________________
6. superior ______________________
7. central ______________________
8. internal ______________________
9. caudal ______________________
10. peripheral ______________________
11. external ______________________
12. proximal ______________________
13. para-sagittal ______________________
14. cephalic ______________________
15. ventral ______________________
16. coronal ______________________
17. lateral ______________________
18. dorsal ______________________
19. superficial ______________________
20. medial ______________________
21. sagittal ______________________
22. frontal ______________________

Fig. 2. Student Handout for SPA 430
(referred to in Sample Question 2)

Sample Question 2--Speech Pathology and Audiology

Sequence No.	Label	Op Code	Argument
bb-0010-210		qu	2.2. If medial (#20) means in the middle, what word on your Handout means to the side?
		nx	
		fn	kw//1
		ca	/ lateral / 17
		ty	Correct
		fn	tape//049
		ty	,,(line feed),,
		fn	tape//050x
		nx	
		ad	-1//c0
		un	Wrong. What word on your Handout is also a term used in football for a pass to the side?
		un	On the sides of geographical areas are *Lat*itudes. Try again.
		un	Try again.

Sample Question 2. The programing in sample question 2 is more complex than that of the previous question. The student is referred to his handout where he will find the answer to the question presented to him. In this case there are two possible correct answers which the authors were willing to accept, i.e., "lateral" or "17." The authors indicated this in the program by preceding the correct answer (ca) with a keyword (kw) function. The keyword function requires only one of the correct answers in the ca to be matched, that is, either "lateral" or "17." If the student matches one of these two correct answers, he gets the typeout (ty) "correct." The tape message is then played for him, the paper in his terminal is advanced with a linefeed command, and the next question is presented. In the event that he does not respond correctly, -1 is added to counter 0 and the first unanticipated (un) answer is typed out for him. The computer checks the counters later in the program to determine appropriate remedial branching. The un tells him that he is wrong and gives him a hint in regard to the correct answer. In the event that he makes repeated wrong responses to the question, the successive un's are presented to him. After the fourth incorrect response, the final un is repeated to him. Table 4.6 presents the responses and the response latency of each student to this question. This analysis shows that students made content errors rather than spelling errors, as was the case in the preceding question.

Table 4.6

Student Responses and Response Latencies for Sample Question 2 from CAI Speech Pathology and Audiology Course Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]
7577	superficial	106.5	lateral	8.2
7578	lateral	19.7		
7579	distal	3.8	lateral	4.2
7580	lateral	3.9		
7581	peripheral	95.0	lateral	8.0
7582	peripheral	20.4	lateral	8.8
7583	lateral	14.9		

[a] In seconds

Sample Question 3--Speech Pathology and Audiology

Sequence No.	Label	Op Code	Argument
cc-0040-410		rd	*3-13.* Locate the kidney shape in the upper left region of the medial wall.
		fn	wait//10
		ty	,,(line feed),,
		qu	*3-14.* This kidney shape is the place where "sound" enters the inner ear. What does this kidney shape represent?
		nx	
		fn	kw//2
		ca	/ oval / window / fenestra / ovalis
		ty	Correct. You might want to label your Handout.
		fn	wait//5
		nx	
		fn	kw//1
		wa	/ footplate / base
		ty	The footplate of the stapes lies within the kidney-shape. However, the arch of the stapes remains within the middle ear cavity. The kidney shape is intended to represent a hole in the medial wall of the middle ear cavity. Try again.
		nx	

Sequence No.	Label	Op Code	Argument
		fn	kw//1
		wa	/ round / rotunda
		ty	This Handout has not distorted the round window into a kidney shape. You should know by now that the round window is not the main sound conducting mechanism leading from the middle ear to the inner ear. Try again.
		nx	
		fn	kw//1
		wa	/ stapes / stirrup
		ty	The footplate of the stapes fits into this kidney shape. What does the kidney shape represent? Try again.
		un	Don't let this Handout confuse you. Following the normal path of sound conduction, what kidney-shaped opening "connects" the middle ear and the inner ear? Try again.
		un	This opening is a window. Try again.
		un	The correct answer is: oval window. Type this.

Sample Question 3. The authors have anticipated two forms of the correct answer - the common English name and the more technical name - and have anticipated six wrong answers which students might make. The question is presented to the student and the system waits for the student to respond. If he responds with any of the two words from the correct answer (ca), it will be counted as correct. This ca is controlled by the preceding keyword (kw) function which specifies that two of the elements of the ca must match. If the student responds correctly, he receives the typeout (ty) "correct," and the suggestion that he might want to label his handout. The system then waits five seconds as specified by the authors so that the student can add the label to his handout. If the student does not respond with the correct answer, the system checks to see if any of the specified wrong answers (wa) have been given. If the student response matches a wa, the following ty is presented to the student and the system waits for the student to respond again with the correct answer. As in the preceding question, the authors have provided for three unanticipated answers with the last one being repeated for each succeeding unanticipated answer. Table 4.7 contains material obtained from student records in the system and indicates that all but one of the students responded correctly on the first trial. One student, after receiving the first un with additional information, responded correctly on the second trial and then proceeded to the next question. The reader should note the wide variability in response latency among five students.

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Table 4.7

Student Responses and Response Latencies for Sample Question 3 from CAI Speech Pathology and Audiology Course Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]
7577	oval window	8.5		
7578	basal end of the cochlea	98.3	oval window	26.9
7579	oval window	7.2		
7580	oval window	6.3		
7581	oval window	41.7		
7583	oval window	135.1		

[a] In seconds

Sample Question 4--Speech Pathology and Audiology

Sequence No.	Label	Op Code	Argument
ii-0070-400		qu	*9-10*. What end-organ is affected by stopping and starting motions?
		nx	
		fn	kw//1
		ca	/macula
		ty	Correct.
		br	qu1//c1//e//1
		ad	-1//c0
		nx	
		ld	1//c1
		fn	pa0//32t//50
		wa	macula
		un	Wrong. Try again.
		un	Type: macula
		rd	
		ld	0//c1
		ty	,,(line feed),,

Sample Question 4. The authors used counters extensively in this program to control the progress and branching of students throughout the instructional strategies. A keyword (kw) function is used to examine the first correct response "macula."

If a match occurs, the student receives the typeout (ty) "correct" and control passes to the following branch (br) statement, which commands the system to branch to the next question if counter 1 equals 1. If this condition is not met, control passes to the add (ad) statement and -1 is added to counter 0 before branching automatically to the next question. If the student's response is not correct and does not match the first ca, the nx statement after the ad statement takes control and immediately passes control to the next load (ld) statement. At this point, 1 is loaded into counter 1 and control passes to the following pa0 function. The pa0 function is checking for the same response as the original kw function specified except that it will examine the student's response in small segments and will require only a 50 per cent match to meet the requirements of the pa0 function. If 50 per cent of the student's response matches the stored "wrong answer," the pa0 function will type the correct answer to the student and will require the student to type the correct answer before proceeding with the course. When the student responds this time, he undoubtedly will make the correct response which will match the first ca. The system will then test the br statement and the student will be branched to the next qu because counter 1 equals 1.

Table 4.8

Student Responses and Response Latencies for Sample Question 4 from CAI Speech Pathology and Audiology Course

Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]	Trial 3	L3[a]
7577	crista	27.2	maculae	29.0		
7579	macula	7.4				
7580	crista	13.1	maculae	22.6		
7581	crista	16.5	otholithic membranes	58.1	macula	9.0

[a] In seconds

Sample Question 5--Speech Pathology and Audiology

Sequence No.	Label	Op Code	Argument
jj-0040-010	#s-51a		
	Anatomical Slide: Schema of Cochlear Canal - labeled.		
		ty	This slide shows a highly diagrammatic cross section of the cochlear canal. This is the same as your Handout, but with the parts labeled. Notice that the cochlear canal is divided into three main parts: (1) the scala vistibuli; (2) scala tympani; and (3) scala media (i.e., the space inside the cochlear duct).
		ty	,,(line feed),,
		rd	Correct your Handout if necessary. Make sure that all parts are labeled. When ready to proceed, press EOB.
		fn	sb///nxl//a0///rmdone
		rd	
		ty	,,(line feed),,
		ty	Here are a couple of questions related to this area.
		ty	,,(line feed),,
		qu	*10-1*. Energy delivered into the footplate of the stapes would be delivered into which scala?
		fn	kw//1

Sequence No.	Label	Op Code	Argument
		ca	/vestibul
		ty	Correct; (i.e., the scala *vestibuli* connects to the *vestibule* and therefore to the oval window area.) Refer to the previous Handout: Membranous Labyrinth to see this illustrated.
		fn	wait//10
		un	Wrong. Your previous Handout: Membranous Labyrinth ought to give you a hint as to the correct answer. Try again.
		un	Type: vestibuli

Sample Question 5. This question begins with an author comment which is indicated in the label field by the number symbol (#). This comment appears in the compile listing only and enables an author to insert reference comments related to specific functions in the course. The course continues with a ty statement to the student which presents information in a sequenced way. The following ty statement is a linefeed command which causes the student's terminal to advance the paper a single or double space for formating purposes. This function enables the author to structure the physical layout of the material which the student is receiving. A read (rd) statement is then presented to the student which instructs him to check his handout and see if it is labeled properly. The next function branches to a subroutine (sb///nxl//a0///rmdone) and then returns to this question to check on certain conditions of the student's counters and his progress. Another linefeed is then activated and new material related to this area is started. The question (qu) is then presented and the system waits for the student to respond. The authors have anticipated only one correct response to this question. If the student makes this correct response, he receives the typeout (ty) which informs him that he is correct and refers to a previous handout. The system waits ten seconds, as specified by the authors, and then proceeds to the next question. If the student responds incorrectly, he receives the unanticipated (un) response "wrong" and is referred to a previous handout. On his second incorrect response, he is given the correct answer and instructed to type it. Table 4.9 indicates that only one student responded correctly on the first trial, one student responded correctly on the second trial, one on the third trial, and one on the fourth trial.

Table 4.9

Student Responses and Response Latencies for Sample Question 5 from CAI Speech Pathology and Audiology Course

Field Trial, Spring 1966

Student Number	Trial 1	L1^a	Trial 2	L2^a	Trial 3	L3^a	Trial 4	L4^a
7577	scala vestibuli	10.9						
7579	scala media	122.1	tympania scala	62.0	vestibuli	5.9		
7580	scala media	67.1	scali typani	14.7	vestubuli	7.5	vestibuli	6.5
7581	scala tympani	137.1	scale vestibuli	54.8				

^{a}In seconds.

Results of Field Trial

Table 4.10 presents the posttest and retention test scores for students who participated in the field trial of the speech pathology and audiology material. Since the retention test was administered the term following the field trial, some students were not available to take the test because they were graduated at the end of the term, withdrew or transferred from Penn State. Table 4.11 presents the mean and standard deviation on the posttest and retention test for each group. A one-way analysis of variance on the posttest scores was performed. The results of this analysis are presented in Table 4.12.

Table 4.10

Posttest and Retention Test Scores for Speech Pathology and Audiology Field Trial Spring, 1966

	Posttest	Retention Test
Self-Study Group		
1	105	--
2	55	10
3	83	22
4	80	29
5	108	36
6	89	39
7	75	--
Lecture Group		
8	91	--
9	88	29
10	102	49
11	92	--
12	92	26
13	91	--
14	114	--
CAI Group		
7577	104	30
7578	56	--
7579	99	--
7580	88	31
7581	75	21
7582	72	--
7583	89	00

Table 4.11

Mean and Standard Deviation for Each Group in the Speech Pathology and Audiology Field Trial Spring Term, 1966

	Lecture Only	Self-Study	CAI
Posttest			
Mean	95.71	85.00	83.28
S. D.	9.18	18.14	16.69
Retention Test			
Mean	14.86	19.43	11.71
S. D.	19.89	16.33	14.95

Table 4.12

One Way Analysis of Variance on Posttest Scores for Speech Pathology and Audiology Field Trial Spring Term, 1966

Source	d.f.	Sum of Squares	Mean Square	F-ratio
Treatment	2	635.14	317.57	1.37
Error	18	4150.86	230.60	
Total	20	4786.00		

CHAPTER V

INTRODUCTORY MANAGEMENT ACCOUNTING

(Joe J. Cramer, Jr. and Carl R. Palmer--Course Authors)

The management accounting course (mana) developed for CAI is formally classified as the basic management accounting course at The Pennsylvania State University. The completed course for CAI was based on two major sources of data. Certain portions of the course were drawn from text materials adopted for current use at Penn State. Appreciation is expressed to McGraw-Hill Book Company, Inc., I. Wayne Keller, and William L. Ferrara (publisher and authors of the second edition of Management Accounting for Profit Control) for granting permission to use these materials in this research project. The second source was "Supplementary Reading Assignments" written by the course authors for the purpose of expanding and clarifying important accounting concepts and procedures. The objective of the teacher of the basic management accounting course - whether a CAI system or the traditional classroom lecture - was to provide an opportunity for each student to gain exposure to selected theoretical aspects of management accounting theories and their role in management planning and control coupled with simulated practical experience (homework problems) which, hopefully, reveal advantages and disadvantages of both conceptual observations and practical applications.

Development of Course for Computer Presentation

Implicit in the previous comments is the fact that management accounting data are vital to decision-making for profit optimization. Consequently, information which facilitates cost control (with implications for cost reduction) is the *sine qua non* on which a management accounting system rests. The completed course includes the following topics

- I. Introduction to Management Accounting
  - A. The responsibility of accounting and dual posting concepts in relation to cost accumulation for (a) control and (b) income measurement permeate the entire course.
  - B. Distinction between accounting procedures for merchandising and manufacturing firms
- II. The Cost Accounting Cycle (accounting for materials, labor, and overhead)
- III. Basic Cost Accounting Systems (historical and standard costing systems)
  - A. Job Order Costing
  - B. Process Costing
- IV. Control of Manufacturing Costs (classification of costs as fixed, variable, and semi-variable for control purposes and usefulness of the flexible budget technique for control of factory overhead costs)

Since the project began, curriculum changes were instituted by the accounting department, some of which were incorporated in the CAI management accounting course.

Nine segments were prepared for CAI. Necessity for extensive revisions of the cost accounting material was traced to five major factors, which are briefly explained as follows:

Modification of original plan to base the course exclusively on text adopted for classroom use. The revised course included assignments based on two introductory cost accounting textbooks. The Keller-Ferrara (1966) text was adopted for use at The Pennsylvania State University, and the Horngren (1962) text served as an important reference for students participating in CAI. Utilization of selected chapters of a second text served two purposes. First, the selected chapters of the Horngren text either complemented and expanded parallel chapters of the Keller-Ferrara text or provided clarification of concepts. Second, several case problems from the Horngren text were used to provide simulated practical applications of cost accounting data.

Remaining portions of the materials ("Supplementary Reading Assignments") were accumulated and/or written specifically for the CAI field trial and were circulated in mimeographed form to participating students. A sample of this material is presented in Appendix E.1. Such reading assignments were prepared for the purpose of expanding and clarifying certain important accounting concepts and procedures which empirical evidence suggested were not readily comprehended by many students. Thus, the cost accounting CAI course represented a comprehensive set of instructional media encompassing the items described above and additional assistance for students as described in the design of the field trial.

Revision based on review of computer printouts of students used in testing the original program. Many of the revisions incorporated in the course were made as a result of intensive review of students' terminal printouts. For example, additional acceptable answers and sufficient hints to "lead" students toward correct or acceptable responses were incorporated in the course. These revisions were immeasurably facilitated as a result of improvements in the Coursewriter language, which provided flexibility in the ability of the hardware for processing student input. Where applicable, new Coursewriter functions and operation codes were incorporated in the revised course.

Inclusion of additional problem materials and quizzes. Incorporation of meaningful progress evaluation schemes for the student was another factor influencing course revision. The evaluation sequences were programed in a manner similar to "quizzes." The purpose of this aspect of course revision was to highlight computer-assisted instruction as a tutorial device which is sensitive to individual differences among students. Evaluation sequences, therefore, were presented as an instructional device designed exclusively for diagnostic purposes and not as a measure of achievement. This technique was used to prompt student review in cases where remedial work was indicated, to correct unsatisfactory progress, and to clarify misconceptions. Throughout the revised course, primary reliance was placed on the student to determine the extent to which remedial materials or reviews were needed. The course used extensive branching, but no effort was made to "force feed" materials to the student. A significant level of preparation of each assignment was assumed and required prior to each session with the computer.

Additional case problems were included so that the student could acquire a form of simulated experience in applying theoretical concepts discussed in assigned reading materials. Case problems were provided prior to computer sessions so that students could read appropriate materials and prepare solutions as component parts of each assignment. A sample of these is presented in Appendix E.2.

Influence of curriculum changes on course revision. The management accounting course underwent substantial changes in purpose, orientation, and content since the project was initiated in April 1964. Curriculum changes instituted by the accounting department changed this course from fifth to second in a series of introductory accounting courses. Additional course content relating to broader management uses of accounting data were included, along with an introduction of the budgetary planning process. Since the course became a requirement for all students in the College of Business Administration, students are more evenly distributed among accounting majors and non-accounting majors. These changes required very extensive revision of the original CAI course.

Reaction of Students. The following comments are based on observations of students who tested parts of the cost accounting program during fall term, 1964. Fifteen students who were concurrently enrolled in the course for college credit volunteered to serve as subjects. Portions of segments 1, 2, 3, and 6 of the program were tested. Students indicated that they were initially fascinated by CAI and impressed by the large degree of student independence which characterized the learning situation, as well as the ability to proceed at their own pace. Three students informed the course author that for the first time during their college careers they were able to ask meaningful questions in class as a result of reviewing terminal printouts.[1] In addition, students expressed great satisfaction for being given an opportunity to participate in a curriculum development project with their classroom instructor. This type of student-teacher association (at the larger university) is usually limited to the graduate student.

Several students became bored after having worked at the terminal for a few sessions. Discussions with these students revealed the following reasons for this situation: Inability to proceed at the same pace as formal classroom assignments because of constraints on computer time and facilities, and necessity to, in effect, prepare "two" assignments - one for actual course credit and the other for the research project. Demands on students' time in view of enrollment in other courses thus accounts for part of this reaction. Some students expressed concern relative to exposure to a new teaching medium or inability to type as proficiently as they would have liked, coupled with the mere idea of having to "operate a machine." Most students subsequently adjusted to CAI if they were permitted to work alone, and if help was available in case of difficulty with hardware and course content.

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[1] These observations may not be applicable in situations where students are exposed to CAI only.

Field Trial

A field trial of the CAI management accounting course was conducted during the spring term, 1966. The purposes of the study were twofold: 1) to investigate the problems involved with providing CAI experience for a number of students on a regular basis for academic credit, and 2) to gather data for improving the course based on student responses and reactions.

Random Assignment of Students. The 36 students who enrolled in Accounting 102.8 were stratified into three levels on the basis of examination grades from the prerequisite course Accounting 101. The students in each of the stratified groups were then randomly assigned to one of the field study conditions - lecture, self-study, or CAI. Five of the students dropped the course shortly after it started. Eight students remained in the self-study group, 10 students in the CAI group, and 13 students remained in the lecture group. All students received a copy of the Course Outline for Accounting 102 (Appendix E.3).

Lecture Group. The 13 students assigned to the lecture group met with the professor three periods (75 minutes each) weekly. This segment of the class group was taught according to the standard procedures used by the professor for a lecture-discussion class.

Self-Study Group. Eight students were assigned to the self-study group. These students met in the lecture group one period each week with the professor and were assigned to the Curriculum Materials Center for two periods each week. Appendix E.4 includes a list of related materials available in the Curriculum Materials Center. Table 5.1 indicates the amount of time spent in the Curriculum Materials Center by each student who was assigned to the self-study group. The students were not informed that a record was being made of the amount of time they spent in the Center, nor was this time used to evaluate the students in any way. It merely indicates that some students spent considerably more time than others in using the specific references placed in the Center.

CAI Group. Ten students were assigned to the CAI group. These students met with the professor and the rest of the class one period each week and were assigned time at the CAI terminal for approximately two periods each week. Appendix E.5 contains a sample of the program with slides and tape-recorded messages, and Appendix E.6 contains samples of static displays.

Table 5.1

Time Spent in Curriculum Materials Center
by Students in the Management Accounting Self-Study Group
Spring 1966

Student	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total	Average Hours/Week
1	4:05	4:25	2:30	3:30	1:55	3:05	3:25	1:30	24:24	3:03
2	1:20	2:30	0	1:10	2:35	0	1:30	0	9:05	1:08
3	2:30	2:35	1:10	0	0	0	0	0	6:15	0:47
4	1:35	2:40	1:10	0	0	0	0	0	5:25	1:48
5	4:05	4:05	3:30	1:05	2:15	2:00	3:10	2:25	22:30	2:34
6	3:00	3:35	1:25	1:10	1:15	1:40	1:10	0:20	13:35	1:42
7	3:30	2:50	2:15	0	0	0	2:15	0	10:50	1:21
8	3:40	4:10	2:25	2:40	3:25	2:20	2:15	2:55	23:50	2:59

Table 5.2 shows the structure and amount of course material stored in the computer. The course is segmented into chapters for ease of handling at the Computation Center; however, a student taking the course goes directly from one chapter to the next if he so desires.

Table 5.2

Structure of CAI Management Accounting Course

Chapters	No. of Coursewriter Instructions	No. of Questions	No. of Slides	No. of Tape-Recorded Messages	No. of Static Displays
1	936	62	39	28	--
2	238	9	9	6	--
3	1006	82	--	--	3
4	800	33	6	--	6
5	556	29	5	--	--
6	1046	10	8	--	6
7	946	81	--	--	1
8	435	29	--	--	--
9	593	88	--	--	7
Total	6556	423	67	34	23

Table 5.3 shows the time spent on computer terminal by the students in the management accounting CAI group.

Table 5.3

Time Spent on Computer Instructional Terminal in the Management Accounting CAI Group Field Trial, Spring 1966

Student Number	Dates Beginning-Ending 1966	Time Hours-Minutes		Average Hours/Week[a] Hours-Minutes	
6752	4/4 - 5/25	16	6	2	1
7326	4/4 - 5/26	18	39	2	20
7327	4/4 - 5/23	12	43	1	35
7328	4/4 - 6/1	20	3	2	30
7329	4/4 - 5/19	18	21	2	18
7330	4/4 - 6/1	21	10	2	38
7331	4/5 - 5/11	12	50	1	36
7332	4/4 - 5/31	27	57	3	29
7333	4/4 - 6/1	26	8	3	16
7334	4/4 - 4/28	9	10	1	9

Total Time - 181 hours

Average time per student - 18 hours and 8 minutes

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[a] Calculated on the basis of maximum number of weeks (eight) on terminal by student from the group.

Table 5.4 shows the character and operand code count for five representative, selected questions from the course. On the basis of the information from these five questions, it is estimated that for the 423 questions and related instructions in the course, there are approximately 377,700 characters in computer storage for the nine chapters.

The entire question and related materials for each of these sample questions is presented on the following pages. Following each question and related material is a table which shows the attempts which each student made to answer that question and the response latency for that trial. This information was obtained from student record analyses from the computer and is representative of one of the benefits that an author can derive from the computer in revising and updating course material.

Table 5.4

Character and Operand Code Count for Five Selected Questions from CAI Management Accounting Course

Op Codes	Ques. 1		Ques. 2		Ques. 3		Ques. 4		Ques. 5		Total f for 5 Qus	Total C for 5 Qus
	f*	C**	f	C	f	C	f	C	f	C		
Primary												
qu	1	112	1	77	1	265	1	62	1	179	5	695
Major												
ca	2	80	2	66	2	68	3	135	2	48	11	397
cb			1	25			2	92	1	24	4	141
wa	1	40									1	40
un	2	172	1	76	2	99	2	596	2	228	9	1171
nx	2	32	1	16	1	16	2	32	1	16	7	112
Minor												
ty	3	108	2	74	2	58	3	294	2	54	12	588
fn	2	59	1	30	1	29	2	51	1	29	7	198
TOTAL	13	603	9	364	9	535	15	1262	10	578	56	3342

*frequency
**Number of characters

Sample Question 1--Management Accounting

Sequence No.	Label	Op Code	Argument
03-0110-000	int3-9	qu	For control purposes, data must be accumulated by __________. Fill in.
		ca	areas of responsibility
		ty	Correct.
		nx	
		fn	pa0//853//90
		ca	areas of responsibility
		ty	Correct.
		nx	
		fn	pa0//853t//50
		wa	areas of responsibility
		ty	Correct your errors; try again.
		un	Remember the definition we gave you a short time ago? It must relate to areas of __________.
		un	areas of responsibility

Sample Question 1. This question is a completion question. The authors have anticipated only one correct answer but have provided several means for processing the student's answer. The first correct answer (ca) "areas of responsibility," must be matched exactly by the student in order to receive the following typeout (ty) "correct." If the student's response does match the ca, the student receives the ty and proceeds to the next question. If the response does not match the stored ca exactly, control passes to the next function which is the partial-answer processing (pa0) function. The authors have determined that the student's response must match at least 90% of the ca in order to be counted correct. The computer will examine the student's response first using a string length of eight characters and then five characters and then three characters to make this decision. If this condition is not met, control passes to the next pa0 function in which the authors have specified only a 50% match with the stored "wrong answer (wa)." If the student's response matches 50% of the stored wa, the student will receive feedback from the pa0 function. The computer will type those portions of the student's response which were correct and dashes for those which were incorrect. In the event that the student's response does not meet the 50% criterion, he then is presented with the unanticipated (un) response in which he is prompted and then again presented with the question. If upon responding again to this question he does not meet the 50% criterion, he is presented with the following un which simply gives him the correct answer to the question.

Table 5.5 shows the responses made by students to this particular question, and the response latencies as recorded in student records. Seven of the nine students made the correct

Table 5.5

Student Responses and Response Latencies for
Sample Question 1 from CAI Management Accounting Course
Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]	Trial 3	L3[a]
6752	areas of responsibility	69.9				
7326	areas of responsibility	14.5				
7327	heads of responsibility	47.2	areas of responsibi$ity	23.4	areas of responsibility	13.0
7328	areas of responsibility	32.4				
7329	areas of responsibility	19.8				
7330	chart of accounts	77.6	areas of responsibility	38.3		
7331	areas of responsibility	53.9				
7333	areas of responsibility	18.8				
7334	areas of responsibility	44.6				

[a] In seconds

response on the first trial. One of the remaining students made the correct response on the second trial, and the other remaining student made a spelling error in his response which meant that he had to type it again on the third trial.

Sample Question 2--Management Accounting

Sequence No.	Label	Op Code	Argument
03-0450-000	st3-4	qu	What is the combination (or summation) element?
		ca	factory overhead
		cb	overhead
		ty	Correct--factory overhead
		nx	
		fn	pa0//543r//85
		ca	factory overhead
		ty	Correct
		un	Incorrect; it's factory overhead. Type it in.

Sample Question 2. This question presents a slight variation in programing to achieve similar results. A correct answer (ca) is followed by an alternate correct answer (cb) which in turn is followed by a typeout (ty). This sequence will cause the same *ty* to be presented to the student whether he matches exactly the *ca* or the *cb*. This flexibility saves a great deal of clerical time, author's writing time, and computer storage space by not having to repeat the *ty* statement for each correct answer. The partial-answer processing (pa0) function contained in this question also uses a variation within the system. The 543 sequence in the function indicates the string lengths that the system will use in searching the student's response to compare it with the stored correct response. The r following this string length means that if the 85% correct criterion is met the feedback to the student will consist of correct portions typed in black and incorrect portions typed in red. As is standard procedure, the last operation code in the qu block is the unanticipated answer (un).

Table 5.6 shows that eight of the nine students responded to this question correctly on the first trial. The ninth student made a spelling error which could have been counted correct if the authors had decided to change the criterion level of the pa0 function. The need for changes like these become quite apparent after student records have been analyzed. With this present CAI system, a change such as this can be made easily and hence a course can be updated regularly on the basis of new information derived from student records.

Table 5.6

Student Responses and Response Latencies for Sample Question 2 from CAI Management Accounting Course Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]
6752	factory overhead	7.0		
7326	factory overhead	10.2		
7327	factroy overhead	11.3	factory overhead	9.8
7328	factory overhead	9.0		
7329	factory overhead	11.0		
7330	overhead	19.0		
7331	factory overhead	8.4		
7333	factory overhead	7.6		
7334	factory overhead	8.7		

[a] In seconds

Sample Question 3--Management Accounting

Sequence No.	Label	Op Code	Argument
03-0980-000	en-7	qu	If the following are three of the four parts of the credit portion to entry C 0, what is the fourth part? cr. federal income taxes payable 15000.00 cr. social security taxes payable 3000.00 cr. union dues payable 1000.00
		ca	cr. cash 92000.00
		ty	Correct
		nx	
		fn	pa0//853//85
		ca	cr. cash 92000.00
		ty	Correct
		un	We have to pay out cash don't we?
		un	cr. cash 92000.00

Sample Question 3. The authors have followed the same procedure with this question as with the previous question. However, the responses the students made to this question (Table 5.7) indicate that the response behavior of the students was not as controlled as was indicated for the other questions examined in this course. Some students required five trials before making the correct response.

Table 5.7

Student Responses and Response Latencies for Sample Question 3
from CAI Management Accounting Course
Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]
6752	cr. cash 92000.00	23.0	yes	30.3
7326	cr. cash $111000.00	20.9	yes	4.2
7327	accrued payroll $107000.00	33.7	dr. cash $19000.00	42.5
7328	Cash	31.5	cash 92000	23.9
7329	cr. cash 92000.00	148.9		
7330	cr. direct labor	86.1	cash920000.00	35.4
7331	dr. state income TAW $92000.00	249.0	cr. cash $92000.00	17.1
7332	dr. wages payable 81000	68.7	cr. cash 81000	26.8
7333	dr. payroll taxes 5000	68.4	yes	7.2
7334	dr. cash92000.00	84.7		

Student Number	Trial 3	L3[a]	Trial 4	L4[a]	Trial 5	L5[a]
6752	dr. cash 92000.00	29.9				
7326	dr. cash92000.00	18.1				
7327	dr. cash $ 92000.00	16.1				
7328	cr. cash 92000	27.5	dr. cash 92000	10.2	dr. cash 92000.00	22.3
7330	dr. cash 920000.00	33.3				
7332	dr. cash 92000.00	30.6				
7333	dr. cash 92000.00	18.9				

[a] In seconds

Sample Question 4--Management Accounting

Sequence No.	Label	Op Code	Argument
04-0380-000	int4-28	qu	Who requisitions the materials and therefore controls or has authority to control the obtaining of materials from the stockroom?
		ca	foreman
		cb	foremen
		ty	Correct.
		nx	
		fn	pa0//43r//80
		ca	foremen
		ty	Correct.
		un	Incorrect. Try again.
		un	Didn't we go over the point earlier? The foremen in the production departments are authorized to issue materials requisitions.

Sample Question 4. The authors have provided for two correct responses to this question. If the student makes either of these correct responses, he will get the feedback "correct." The author has also provided for some degree of misspelling by using the pa0 function with criterion level of 80%. If a student does not reach this criterion, he receives the first un; on the second trial if he still has not reached the criterion level, he receives the second un which contains the correct answer. Table 5.8 presents the student responses and response latencies for this sample question in the management accounting course. In checking this portion of student records, Student 7330 presented a slightly different problem. On trial 1 he made a correct response; on trial 3 he made a correct response with an incorrect response on trial 2. An inspection of the times and dates recorded in student records revealed that the student responded correctly to this question the first time and then signed off. He returned the following day to continue with his study. In the event that a student signs off in the middle of a segment and then continues at a future time, the last question presented to him before sign-off will be presented again at the beginning of the next sign-on of that segment. This provides a slight amount of overlap in the work that a student does in the program but also provides some review for the student who is signing on to the program.

Table 5.8

Student Responses and Response Latencies for Sample Question 4 from CAI Management Accounting Course Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]	Trial 3	L3[a]
6752	production control department	62.2	foreman	22.2		
7326	foremen	6.1				
7328	the head of the individual departments	45.6	storekeeper	39.7	foreman	6.3
7329	foreman	35.2				
7330	foreman	17.0	production control personel	45.0	foremen	9.2
7331	foreman	53.1				
7332	foreman, production control department	38.2	foreman	20.1		
7333	foreman	10.0				
7334	foreman	21.1				

[a] In seconds

Sample Question 5--Management Accounting

Sequence No.	Label	Op Code	Argument
03-1000-000	en-9	qu	What is the debit portion of entry d o?
		ca	dr. factory overhead 17000.00
		cb	dr. factory overhead control 17000.00
		cb	dr. overhead 17000.00
		ty	Right
		nx	
		fn	pa0//853//85
		ca	dr. factory overhead 17000.00
		ty	Okay
		nx	
		fn	kw//3
		wa	dr., factory , overhead
		ty	The account is factory overhead, what is the amount? Remember entry b o and the fact that total factory overhead per the statement is 28000. Type the entire debit portion of the entry as your answer, please.

Sample Question 5. This question presents an example of the problems involved with programing for multiple word answers. The first correct answer (ca) and the first and second correct answers (cb) provide the exact answers in storage which the student might be able to match. However, it is very unlikely that a student would enter this response exactly as the author had planned it to the extent of changing abbreviations or spacing or even the order of the elements in the answer. Therefore, the author has provided two other processing functions to allow variation in student responses. The first function (pa0) presents the same answer in the following ca but requires only an 85% match with the student's response to be counted as correct. This function in addition to allowing variations in the sequencing of the elements in the response would also allow for slight misspellings within any of the elements. The following function (kw) allows for the changed sequence of the three elements but will not allow for any misspelling within the three elements. It is apparent from the student records presented in Table 5.9 that the author is allowing some responses to be considered correct which essentially are not correct. The partial-answer processing requiring only 85% match allows enough flexibility in the student response that the $17000 does not have to be matched precisely. Student 7328 entered $18000 and was permitted to proceed to the next question. Likewise, student 7331 entered $13,000 and proceeded to the next question. At this point the authors are more concerned with the concepts involved in management accounting rather than in the specific details of amounts and values.

Table 5.9

Student Responses and Response Latencies for Sample Question 5 from CAI Management Accounting Course Field Trial, Spring 1966

Student Number	Trial 1	L1[a]	Trial 2	L2[a]
6752	dr. factory overhead 17000.00	18.0		
7326	factory overhead 17000.00	61.1		
7327	dr. factory overhead $12000.00	25.6		
7328	work in process 28000.00	39.0	dr. factory overhead 18000.00	73.7
7329	dr. accrued payroll 111000.00	47.0	dr. factory overhead 17000.00	85.4
7330	dr, accrued factory overhead28000.00	78.7		28.3
7331	dr. work in process $21000.00	100.3	dr. factory overhead $13000.00	39.9
7332	dr. factory overhead 17000	34.1		
7333	dr. work in process 18000	46.4	dr. factory overhead 17000	69.2
7334	dr. factory overhead 17000.00	26.9		

---

[a] In seconds

Results of Field Trial

The criterion measures on each of the students in the management accounting field study are presented in Table 5.10. Because some of the students involved in the field study were graduated at the end of the term, withdrew or transferred from Penn State, retention test could not be administered and scores are not available.

Table 5.10

Criterion Measures of Students in Management Accounting Field Trial Spring Term, 1966

Student	Exam I	Exam II	Home-work	Final Grade	Retention Test
Self-Study Group					
1	B	D	F	C	--
2	F	F	F	F	--
3	C	F	F	D	--
4	D	F	F	D	--
5	D	C-	A	C	50
6	F	F	F	F	27
7	C	C-	F	C	--
8	D	D-	F	D	--
Lecture Group					
9	C	C-	A	B	--
10	D	D-	F	D	26
11	B	D	F	C	--
12	A	A	A	A	--
13	B	m a*	F	C	--
14	F	X	F	X	--
15	C	C-	A	C	--
16	F	C-	A	C	--
17	D	D+	F	D	--
18	B	D-	F	C	--
19	A	C-	F	B	36
20	F	F	F	F	27
21	F	WF	F	WF	--
CAI Group					
6752	F	F	F	F	--
7326	D	D	F	D	50
7327	F	D+	F	D	15
7328	F	D+	F	D	--
7329	F	F	F	F	8
7330	F	F	F	F	--
7331	C	D	F	D	--
7332	B	C-	F	C	80
7333	F	F	F	F	28
7334	A	C-	F	B	33

CHAPTER VI

ENGINEERING ECONOMICS

(Carl R. Moss and David A. Gilman--Course Authors)

The engineering economics (engecon) course prepared for CAI was for advanced undergraduate and graduate students preparing for careers in industrial engineering, other engineering specialties, or business. The course included problems in investment, equitable return, and cost methods of analysis.

The CAI program for engineering economics utilized visual material in the form of slide presentations. However, the principle components of the course were static displays and student-computer interaction.

The strategy of instruction for the program used the following basic assumptions:

1. The solution of numerical problems is both an aid to and an indication of understanding of economics concepts.
2. Remedial instruction should be contingent upon the type of error made by the student.
3. Active participation by a student produces a more effective learning experience.
4. Knowledge of one's progress contributes to effective learning.

The engineering economics CAI course underwent substantial change in orientation and content in preparation for the field trial. Some display material was converted to slide presentations. Partial-answer and keyword functions were added to make the course more flexible. Still, there were some instances in which the student did not react to questions in the manner that the authors had anticipated. The experience gained by the authors in this regard emphasized the necessity to phrase questions so that the intent of the author is clearly communicated to the students.

Field Trial

A field trial of the CAI engineering economics course was conducted during the summer term of 1966. The purposes of the study were twofold: 1) to investigate the problems involved in providing CAI experience for a number of students on a regular basis for academic credit, and 2) to gather data for improving the course based on student responses and reactions.

Random Assignment of Students. The 20 students enrolled in the class were randomly assigned to one of the field trial conditions - lecture, self-study, or CAI. All students enrolled in the course received a copy of the course outline, which appears in Appendix F.1.

Lecture Group. The seven students assigned to the lecture group met with the professor three periods (75 minutes each) weekly. This segment of the class group was taught according to the standard procedures used by the professor for a lecture-discussion class.

Self-Study Group. Seven students were assigned to the self-study group. These students met in the lecture group one period each week with the professor and were assigned to the Curriculum Materials Center in the College of Education or the Engineering Library two periods each week. The special reference materials which were placed in these locations for individual study are listed in the course outline for the course (Appendix F.1).

CAI Group. Six students were assigned to the CAI group. These students met with the professor and the rest of the class one period each week and were assigned time on the CAI terminal for approximately two periods each week. Appendix F.2 contains a sample of the CAI engineering economics program and includes samples of the slide display and tape messages in the program.

Table 6.1 shows the structure and amount of course material stored in the computer. The course is segmented into chapters for ease of handling at the Computation Center; however, a student taking the course goes directly from one chapter to the next if he so desires. Table 6.2 shows the time spent on instructional terminal for the students in the engineering economics CAI group.

Table 6.3 shows the character and operand code count for five representative, selected questions from the course. On the basis of information from these five questions, it is estimated that for the 794 questions and related instructions in the course, there are approximately 396,137 characters in computer storage for the six chapters.

Table 6.1

Structure of CAI Engineering Economics Course Field Trial, Summer 1966

Chapter	No. of Coursewriter Instructions	No. of Qu's	No. of Slides	No. of Tape Messages	No. of Static Displays
engecon101	356	28	5	7	8
ee2	1142	173	--	--	11
ee3	961	78	--	--	22
engecon104	769	61	--	--	7
engecon105	589	51	--	--	11
engecon106	323	403	--	--	2
Total	4140	794	5	7	61

Table 6.2

Time Spent on Computer Terminal by Students in the Engineering Economics CAI Group Field Trial, Summer 1966

Student Number	Dates Beginning-Ending 1966	Time Hours-Minutes		Average Hours/Week[a] Hours-Minutes	
0028	6/29 - 8/9	13	33	2	16
0031	6/29 - 8/10	8	31	1	25
0037	6/29 - 8/2	17	6	2	51
0125	6/30 - 8/9	12	22	2	4
0961	6/27 - 7/21	9	23	1	34
0967	6/28 - 8/2	10	59	1	50

Total Time - 71 hours and 54 minutes
Average time per student - 12 hours

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[a] Calculated on the basis of maximum number of weeks (six) on terminal by student from the group.

Table 6.3

Character and Operand Code Count for Five Selected Questions
from Engineering Economics Course
Field Trial, Summer 1966

	Ques. 1		Ques. 2		Ques. 3		Ques. 4		Ques. 5		Total f for 5 Qus	Total C for 5 Qus
Op Codes	f*	C**	f	C	f	C	f	C	f	C		
Primary												
qu			1	366	1	96	1	167	1	436	4	1065
Major												
ca			1	58	1	47	2	51	1	21	5	177
cb												
wa			1	43	1	32					2	75
un			3	276	2	201	3	118			8	595
nx			2	32			2	32	1	16	5	80
Minor												
ty	1	196	2	401	2	160	2	147	2	86	9	990
fn	—	—	2	44	2	45	2	44	1	22	7	155
TOTAL	1	196	12	1220	9	581	12	559	6	581	40	3137

*frequency
**Number of characters

The entire question and related materials for each of these selected sample questions are presented on the following pages. This field trial was conducted partially on the 7010 computer located at the T. J. Watson IBM Research Center in Yorktown Heights, New York, and partially on the 1410 computer located at the Computation Center on Penn State Campus. Therefore some of the data which is normally available from student records were not available for this field trial. Following each question and related material is a table which shows the attempts which each student made to answer that question. This is an example of the benefit that an author can derive from the computer for revising and updating course material.

Sample Question 1--Engineering Economics

Sequence No.	Label	Op Code	Argument
		rd	Why is accounting important to economic analysis? Write a statement or list on a piece of paper. When you are finished (EOB).
		rd	
		ty	Your statement should be something like the following: Historical cost data, assets, liabilities, and ownership are found in the accounting reports of an organization.

Sample Question 1. This particular question has a unique value; it demonstrates that essay questions can be presented in CAI. Even though the author does not get specific data on the student's response, the student does gain some benefit by being questioned and responding in a free form. The computer system cannot accommodate a response of more than 99 characters; therefore, no student records were available on the responses to this particular question.

Sample Question 2--Engineering Economics

Sequence No.	Label	Op Code	Argument
	1-9	qu	On a short run order of 1,000 pieces, it requires 2 hours of labor at $2.50/hr. to fabricate a part at the bench. This same product can be fabricated in 1 hr. if a jig is made to aid in its production. How much can be paid for the jig, the product still not costing any more, if material and all other costs remain the same?
		nx	
		fn	kw//2
		ca	#$#2500 #2500.#2500 #2,500 #2,500.#ollars
		ty	Very good. $2,500 represents the break-even point; that is, if a jig did cost $2,500 it would cost as much to produce the 1,000 parts without the jig as with the jig. $2,500 is the maximum that could be paid for the jig without increasing production costs.
		br	1-10
		nx	
		fn	kw//1
		wa	#2500 #2,500 #2500.#2,500.
		ty	Incorrect. Be sure to type both number and units. Also, be sure to space between number and units.

Sequence No.	Label	Op Code	Argument
		br	1-9-1-1
		un	Your answer is incorrect. Try again.
		un	Incorrect. Hint: The break-even point of both alternatives will give you the amount you can pay for the jig. Try again.
		un	The correct answer is $2,500. Type *$2,500*.*

Sample Question 2. Question 2 illustrates some of the problems involved in processing numerical answers. The correct response is processed using a keyword (kw) function. The function specifies two key words which the student must match. The following correct answer (ca) includes all of the forms of the correct answer which the author is willing to accept. One of the correct words which the author is assuming will be present is either the dollar sign or the word dollars spelled out. The other key word the author is expecting is 2500 written in the various forms which it might assume with the variations of decimal points and commas. If the student matches two of these key words, he receives the following typeout (ty) and is branched to the next question. The author has also anticipated a wrong answer (wa) which he assumes will be the absence of the unit sign of the numeral. If the student omits the unit sign, the author tells him that he is incorrect and to include it. The author has also provided for three unanticipated responses which the student will receive in succession.

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*N.B. Material in italics indicates this will appear in red on the printout.

Table 6.4 presents the responses which students made to this question. Three of the five students made a correct response the first time. One of the remaining students required three trials to get the correct response and the remaining student required four trials to get the correct response. It is interesting to note that student number 0967 on his fourth trial imbedded the correct response within a sentence. Because the program was written to incorporate the keyword function, the key word, i.e., $2,500 was taken from the student's answer and accepted as correct by the system.

Table 6.4

Student Responses for Sample Question 2
from CAI Engineering Economics Course
Field Trial, Summer 1966

Student Number	Trial 1	Trial 2	Trial 3	Trial 4
s0031	$2500			
s0967	2,500	$5,000	help	i said that once $2,500
s0961	$2.50	$5.00	$2500	
s0035	$2500.00			
s0037	$2500.00			

Sample Question 3--Engineering Economics

Sequence No.	Label	Op Code	Argument
		rd	Read paragraph 03-17. (EOB)
	c17-2		
		qu	How would you write the equation for the general case of the cost function?
		nx	
		fn	kw//5
		ca	#c#=#mg#Mg#mG#MG#+#b
		ty	Good.
		nx	
		fn	kwo//5
		wa	#y#=#mx#+#b
		ty	This is the generalization for a straight line. What would y and x be in the cost function 1. Try again.
		un	Hint: substitute C and g for y and x in the general equation for a straight line.
		un	The correct answer is c + mg + b.
		br	c17-3

Sample Question 3. This question illustrates another important variation of the keyword (kw) function. In numerical responses it is often very important that the key word elements appear in the proper sequence. The system incorporates the function called keyword order (kwo) which will check not only for presence of key words, but also for the order of these key words. Following the kwo function is the correct answer (ca) with which the function will compare the student's response for processing. Delimiters must be used to separate the individual words or elements considered to be words when the kw function is used. In this example the dollar sign has been used as a delimiter. Any characters which occur between dollar signs are considered to be one key word. It can therefore be seen that in this example there are eight key words of which the author is requiring only five. The student must respond with the following key words in the proper order regardless of whether they are uppercase or lowercase characters and regardless of whether or not spaces have been inserted between them -- c = mg + b.

The student records for this question (Table 6.5) indicate that even with the planning done by the author, the students encountered considerable difficulty in responding correctly to this question. The author has provided for two unanticipated answers (un) and following the last one, which informs the student of the correct answer, the author has automatically branched the student to the next question.

Table 6.5

Student Responses for Sample Question 3 from CAI Engineering Economics Course Field Trial, Summer 1966

Student Number	Trial 1	Trial 2	Trial 3	Trial 4
0031	c=mq+b	c=mq+b+fc	c=mg+b	
0967	c=change in direct labor/change in activity+insection of direct labor	c=mg+b		
0097	y=mx+b	c=mq+b	c=mg+b	
0037	y # mx & b	c # @yz@x &	C # % @y/@x * q & b	Cost # % @ C/ @g * q & b
0028	c = mx + b	c=mq&b	c = mg + b	

Sample Question 4--Engineering Economics

Sequence No.	Label	Op Code	Argument
	e9-7	qu	What is the present value of the capital recovery plus return on investment of the second year of the sum-of-digits method of depreciation?°
		nx	
		fn	ic//6
		ca	$2783.03
		ty	Correct.
		nx	
		fn	ic//7
		ca	$2,783.03
		ty	Correct.
		un	Incorrect. The desired value is found by:
		ty	$3127 (0.8900) = $2783.03
		ty	Give the correct answer.°
		un	Try again.°
		un	The correct answer is: $2,783.03. Type *$2,783.03*.
		rd	Read the last page of paragraph 05-09. Then press *EOB*.°

°Indicates a programed ribbon shift command which causes student's response to be typed in red.

Sample Question 4. This question illustrates two interesting strategies: 1) ribbon shift to cause the student's responses to be typed in red and 2) initial character processing for numerical responses. The author has under his control the color of the ribbon which will be used to type responses and material for the student. By providing a ribbon shift command at the end of each sequence which is to be typed by the system, the author can cause all student responses to be typed in red. The ribbon shift command consists of two characters, one non-printing character identified "prefix" followed by either a (meaning shift to red) or b (meaning shift to black). The argument for question 4 is followed by the non-printing "prefix" and the character a. The ty following the first un and the second un are both followed by the prefix a characters which change the ribbon color to red and give control of the terminal to the student. The ribbon shift feature is also illustrated in the final un and in the following rd statement. In each case the student is told to press EOB, which is the signal to the system that the student is ready to proceed; and the EOB is preceded by a "prefix a" sequence and followed by a "prefix b" sequence. This causes the ribbon to shift to red before "EOB" is typed and then shift to black for the following typing. This flexibility is quite desirable when the author wants the student to type a particular response or to respond in a particular way. Authors have encountered problems occasionally when other techniques were employed for indicating a particular and specific response that the student should make. For example, some authors have tried underscoring the particular response the student should make and others have tried enclosing that specific response in quotation marks. The results of these attempts were that if the author had underscored the answer, the student would underscore the answer; or if the author had enclosed the correct answer in quotation marks, the student would enclose his response in quotation marks. In most cases, because of the inclusion of these extra characters, the response will not be accepted by the system as a correct response. The ribbon shift feature has the advantage of presenting the response exactly as it is to appear except for color over which the student has no control.

The second interesting feature of this sample question is the initial character (ic) function. The first ic function specifies six characters which must match. This function is followed by the ca upon which it is processing. The figure 6 in the ic function specifies that the system will match the student's response only to the first six characters of the stored ca. In this case it means that the system would ignore the last two characters, 03. The following ic function specifies seven characters which must match. This function will also ignore the 03 (three cents) at the end of the response but allows the student to include a comma separating the hundreds and thousands.

Student records for this question (Table 6.6) indicate that it was a relatively easy question for the students to answer and that the initial character function was operating to good advantage.

Table 6.6

Student Responses for Sample Question 4
from CAI Engineering Economics Course
Field Trial, Summer 1966

Student Number	Trial 1	Trial 2	Trial 3
0031	$2783.03		
0028	$2783	$2783.03	
0097	2780	2783.03m-	$2783.03
0125	$2374	$2783.03	
1035	$2783.03		

Sample Question 5--Engineering Economics

Sequence No.	Label	Op Code	Argument
	f105-01-20	rd	
		ty	*06-02.* ,,
	f2-1	rd	Read paragraph 06-02. *(EOB)*
	f2-2	qu	The company described in paragraph 06-02 probably expects at least 10% return on its investment because: a. It can get at least this much in some other type of investment. b. Anything under 10% would not be considered by management as enough return to justify the investment. c. Both *a* and *b*. d. Some other reason. Answer as *a*, *b*, *c*, or *d*.
		nx	
		fn	kw//1
		ca	# C
		ty	,, is correct. Both *a* and *b* are very closely related. Management will probably not accept anything under a 10% return if it can receive at least that much in some other investment.

Sample Question 5. This question permits only one trial for a response and then reaffirms the correct answer by providing the ty. The ribbon shift feature is used to emphasize the particular items which must appear in the student's response. Multiple choice questions have been found to be very useful in CAI inasmuch as the amount of typing that a student must do is reduced. This eliminates much frustration for some students and allows them to proceed smoothly through a course.

Table 6.7

Student Responses for Sample Question 5
from CAI Engineering Economics Course
Field Trial, Summer 1966

Student Number	Trial 1
0125	c
0028	c
0037	c
0097	a
0082	d

Results of Field Trial

Table 6.8 presents the term in attendance, grade point average, and performance of students in the engineering economics field trial. Two essay tests were administered to the students during the term. The scores on these were converted to T scores and an average T score was derived from the two independent scores. Table 6.9 presents the mean and standard deviations compiled from the average T scores for each group in the engineering economics field trial. A one-way analysis of variance on average T scores was performed. The results are shown in Table 6.10.

Table 6.8

Term in Attendance, Grade Point Average, and Performance of Students in Engineering Economics Field Trial
Summer Term, 1966

Student	Term	Grade Point Average	1st Essay	2nd Essay	T-First	T-Second	T-Average
Lecture Group							
1	Gr	N/A*	49.00	69.50	40.81	59.49	50.15
2	Ad	2.20	62.50	35.00	55.03	40.03	47.53
3	Gr	3.00	42.00	40.00	33.43	42.85	38.14
4	10	2.33	66.00	50.50	58.72	48.77	53.75
5	12	2.18	62.00	44.50	54.50	45.39	49.95
6	Gr	2.69	64.00	30.00	56.61	37.21	46.91
7	Gr	2.80	54.00	62.00	46.08	55.26	50.67
8	12	2.32	57.00	20.00	49.24	31.57	40.40
CAI Group							
9	10	1.86	57.00	53.00	49.24	50.18	49.71
10	Ad	2.53	56.50	50.00	48.71	48.49	48.60
11	7	2.64	41.00	45.50	32.38	45.95	39.17
12	Gr	3.00	62.50	83.00	55.03	67.11	61.07
13	Gr	2.75	64.00	68.50	56.61	58.93	57.77
14		1.90	48.00	38.00	39.75	41.72	40.74
Self-Study Group							
15	12	2.22	39.50	57.00	30.80	52.44	41.62
16	Gr	3.21	65.50	85.00	58.19	68.24	63.21
17	8	2.02	62.00	42.50	54.50	44.26	49.38
18	Gr	N/A*	65.00	62.50	57.66	55.54	56.60
19	Gr	2.98	78.00	81.00	71.36	65.98	68.67
20	12	2.06	59.00	36.00	51.34	40.59	45.97
	Raw Means =		57.73	52.68			
	Standard Deviations =		9.49	17.73			

*Student from outside United States.

Table 6.9

Mean and Standard Deviations for Lecture, Self-Study, and CAI Groups Engineering Economics Field Trial Summer Term, 1966

Compiled from Average T-Scores	Lecture	Self-Study	CAI
Mean	47.18	54.24279	49.5
S.D.	4.58220	9.53628	8.08649

Table 6.10

One Way Analysis of Variance on Average T-Scores for Engineering Economics Field Trial Summer Term, 1966

Sources	Sum of Squares	Degrees of Freedom	Mean Squares	F
Groups	154.30600	2	77.15300	1.14016
Within	1150.36300	17	67.66841	
Total	1304.66900	19		

CHAPTER VII

MODERN MATHEMATICS

(C. Alan Riedesel and Marilyn N. Suydam--Course Authors)

The strategy of instruction for the modern mathematics (modmath) program was based on several assumptions concerning the teaching-learning process. These were:

1. Mathematics is best learned when students are encouraged to discover the basic ideas, laws, or principles of mathematics. Thus, students should be given a chance to solve a new problem themselves rather than first being "shown" or told how to solve it
2. The reason for studying a topic should be made clear by the manner in which it is introduced.
3. Individuals vary in their receptivity for learning.
4. Effective learning is continuous and developmental in nature; thus, previous generalizations and facts are helpful in developing new generalizations.
5. Continual failure by an individual is not conducive for effective learning.
6. Active participation by the student tends to produce an effective learning experience.
7. Knowledge of one's progress contributes to effective learning.

A belief in these assumptions led to a teaching procedure in which the student was presented with a problem that could be solved by his use of previous knowledge and his thoughtful discovery of the next step of knowledge in the subject. This approach could be called an inductive approach. A deductive approach is usually used in programmed materials. The following diagram contrasts these two approaches to teaching mathematics:

Inductive Approach		Deductive Approach
Student is presented with a problem.		Student is presented generalization.
If problem is solved by student, he is led to refine his procedure for solving problems of this type.	If student cannot solve problem, he is asked developmental questions which lead to the solution. Student solves similar problem.	Student is quizzed concerning aspects of the generalization.
Student is asked to develop a generalization.		Student is presented with illustrative problems in which the process of solution is explained to him.
Student is quizzed concerning aspects of the generalization.		Student applies the generalization to solving problems.

In the modern mathematics CAI course the use of a teaching technique similar to the inductive pattern was attempted. An illustration of such a pattern for classroom use is as follows:

Purpose of the lesson: To develop an understanding of the use of the inverse (reciprocal) in dividing rational numbers.

The teacher stated: "We've been solving division problems involving the use of rational numbers in several ways. Now let us see if we can find a more efficient method of solution. What are various ways in which we can write 6 ÷ 3/4?"

The following ways were suggested by the students:

(a) $6 \div 3/4 = N$

(b) $\dfrac{6}{\frac{3}{4}} = n$

(c) $\frac{3}{4}\overline{)\,6}$

The teacher said: "Look at form (b) $\frac{6}{\frac{3}{4}}$. If we could reduce this fraction, we could solve the problem. What would be the denominator that would make reduction of the fraction simplest to perform?"

Pupils suggested that the easiest fraction to reduce would be a fraction with a denominator of 1. The teacher asked: "How could we change the denominator from 3/4 to 1?"

Students recalled that by multiplying by the inverse - the reciprocal of 3/4, which is 4/3 - the denominator would be 1. Pupils then said that if the denominator was multiplied by 4/3, the numerator would also have to be multiplied by 4/3 (an application of the role of the identity element for multiplication which is 1. $\frac{\frac{4}{3}}{\frac{4}{3}}$ is another name for 1).

The resultant problem was written on the chalkboard in the following form:

$$\frac{6 \times \frac{4}{3}}{\frac{3}{4} \times \frac{4}{3}}$$

Students continued to work division problems in this manner for a time. When the teacher felt that the students had a good understanding of this approach, discussion and guided questions were used to develop the idea that it is not actually necessary to write all of the material - actually, inverting the divisor accomplishes the desired result. Thus

$$5 \div \frac{1}{2} = 5 \times \frac{2}{1} = 10$$

$$\frac{5 \times \frac{2}{1}}{\frac{1}{2} \times \frac{2}{1}}$$

A teacher using a deductive format for the teaching of inversion would have first explained the approach to the class and then had the students practice its use.

Certain problems arose in applying the inductive technique to the writing of the modern mathematics course. Initially, to transfer a concept of an ideal situation to a programing mode was difficult because of dealing with an imaginary student. It was especially hard to anticipate student answers; the possibilities seemed infinite at times. There was the tendency, therefore, to write a linear pattern with many multiple-choice items. The linear pattern gave assurance that everyone would see the (sometimes) clever things that had been written. The multiple-choice item limited the student's choice and therefore the difficulty of having to deal with the unanticipated when, by definition, it could not be anticipated. Partial-answer processing functions helped to resolve this problem when they became available. Another difficulty in a course designed primarily for future teachers was finding real life situations which made sense to adults and also which could be applicable at an elementary level. Transfer to a real elementary classroom situation was essential;

hopefully, the method by which the material was taught to teachers would affect their own teaching procedures.

Some difficulty was met in determining "size of steps" in asking the questions which led from one point to the next. This involved a value judgment, and it was found that step size varied with the type of material.

Determining the patterns of learning for various students was an even greater problem. The amount of practice and remedial material, the type of vocabulary, the type of learning structure - in short, the needs of individual students - had to be considered. Some branching opportunities were provided on the basis of each of these variables and more should be added as additional student records are analyzed.

Traditional materials provided little real help except for basic content guides since they operate from a different framework. Meaningful problem situations are generally lacking in them; deductive, rule-stating approaches are frequently used; there is a heavy emphasis on vocabulary rather than on concept-formation. We visualized the best type of teaching-learning situation, on the other hand, and tried to lead the student to discover concepts and broader principles.

We felt hampered because the system handicaps a student in being "creative" - he has to conform to our expectation of what answers were probable, possible, and acceptable. Structuring the program through an "inductive" or "discovery" approach seemed vital to counteract, in part, this handicap. There was definitely a need for additional contacts with a teacher and/or other discussion situations to allow questioning, even more inductive problem-solving, and creative thinking.

Development

The CAI modern mathematics course provides the background for understanding mathematical content and concepts of the system of real numbers and its component systems, including basic set theory, varying numeration systems, operations, properties, and algorithms. The program was developed with reference to teaching in the elementary school. Appendix G.1 contains an outline of the topics considered in the course.

The breadth of the program proved to be a limitation - there was a great deal of material to program. The pressure produced by volume was compounded by time - the need to complete the entire program within the specified number of months. Because of this pressure, much more of a Skinnerian or linear program (with comparatively few branches) resulted, and the potential of CAI was perhaps not fully utilized.

However, a final outcome was a course which "runs" and from which students have learned. In fact, two parallel courses are available: one which is identified as mavmath has tape-recorded messages and random-access 2 x 2-inch slides controlled by the computer (see sample of program, Appendix G.4); the other identified as modmath uses a book of static displays in lieu of the

3

tape messages and slides. The content of the two courses is identical, though much additional time was taken to insert the additional functions and to restate some directions for the mav-math program.

While the details of the procedural steps used in developing the program differed for each chapter, they are approximated as follows:

1. Develop outline with the amount of detail differing with the topic. Use was made of two basic sources -- Theory of Arithmetic, by Peterson and Hashisaki, and Arithmetic, Its Structure and Principles, by Mueller - and many additional supplementary references.
2. Delineate principal questions, which led to development of the content of the outline.
3. Complete the writing, using Coursewriter instructions, branching to meet individual needs.
4. Reread, then rewrite; reread, then rewrite - generally two or three repetitions of this were involved at this stage. Discussion between the authors was important here as at other stages.
5. Have program typed; reread for accuracy and make any changes apparently necessary.
6. After the program is in the computer, at least one rereading is necessary, reading for errors in input and any other errors that were apparent; then rewrite.
7. After students worked through a section, more revision was done with reference to their comments and answers, which were analyzed and evaluated. (Continuous evaluation and rewriting was, obviously, necessary!)

Field Trial

A description of a field trial of the modern mathematics CAI course is presented in an article (see Appendix H.2) written by the authors of the course and is quoted here:

> "The course used in this study was programed on the basic mathematics content of Math 200, for freshmen and sophomores in the elementary education sequence at PSU. In addition to the course text, other references were used as content guides in writing the program. The material was divided into fourteen chapters, with the following indicative titles: Sets; Relations; Exponents; Our Numeration System; Other Numeration Systems; Whole Numbers: Addition, Subtraction, Multiplication, Division; Integers; Rational Numbers: Fractions, Decimals, Ratio and Percent; and Real Numbers.
>
> "The problem that was explored referred to the value of CAI - how does it affect the achievement of a group compared with the achievement of a group in the traditional class pattern?
>
> "The population - all freshman students in the elementary education and special education curricula at Penn State who were scheduled for Math 200 during the spring term of 1966 - were assigned to sections, at random, by a computer. From the four sections, one was selected at random. The 26 students in the section (all women) were pretested with a 40-item test o[illegible] mathematical content developed by the authors (Kude[illegible]ichardson Formula 20, r = .82); the results were used as a basis for selecting ten matched pairs of students. One member of each pair was randomly assigned to the CAI-treatment group and one to the teacher-treatment group.
>
> "All students in the section met together for one standard 75-minute period per week for discussion that centered on their questions in regard to content. Both groups used the text Theory of Arithmetic, by Peterson and Hashisaki, and both were provided with the same study guides. The instructor of the course was co-author of the CAI program, and he used the same outline for the class as had been used in developing the CAI program. Both groups were considering the same topics each week. As a measure of control on outside-of-class practice, the answers to study guides were collected.

> "The teacher-treatment group met twice a week for class periods of 75 minutes each. The instructor developed the mathematical content inductively, to parallel the premises of the CAI program. The CAI-treatment was scheduled for 2 1/2 hours per week on the computer, equivalent to the time spent by the teacher-treatment group. Instruction and testing occurred within a standard ten week term."

Several analyses of the program have been made. Table 7.1 shows the structure and amount of course material stored in the computer for the mavmath program. Table 7.2 shows the time spent on computer terminal by the students in the modern mathematics course. Table 7.3 shows the character and operand code count for five representative, selected questions from the course (mavmath). On the basis of the information from these five questions, it is estimated that for the 1191 questions and related instructions in the course, there are approximately 642,816 characters in computer storage for the 14 chapters.

Table 7.1

Structure of CAI Modern Mathematics Course Field Trial, Spring 1966

Chapter No.	No. of Coursewriter Instructions	No. of Qu's	No. of Slides	No. of Tape Recorded Messages
1	642	66	21	22
2	510	55	6	1
3	351	44	5	6
4	243	22	4	4
5	1377	139	25	17
6	1466	143	39	35
7	1116	119	30	10
8	1132	118	33	9
9	1017	102	24	8
10	642	72	10	2
11	1200	127	10	5
12	661	64	10	0
13	663	55	19	7
14	745	65	22	12
Total	11765	1191	258	138

Table 7.2

Time Spent on Instructional Terminal by Students in the Modern Mathematics CAI Group Field Trial, Spring 1966

Student Number	Dates Beginning-Ending 1966	Time Hours	Time Minutes	Average Hours/Week[a] Hours	Average Hours/Week[a] Minutes
0030	4/9 - 6/10	17	10	1	54
0031	4/9 - 6/8	24	31	2	43
0032	4/9 - 6/8	28	50	3	12
0022	4/6 - 6/8	29	27	3	16
0024	4/7 - 6/6	29	26	3	16
0029	4/12 - 6/8	29	41	3	18
0028	4/7 - 6/3	21	6	2	19
0025	4/7 - 6/6	24	45	3	41
0023	4/7 - 6/3	27	9	3	1
0033	4/9 - 6/7	27	33	3	4

Total time - 259 hours and 28 minutes

Average time per student - 25 hours and 53 minutes

---

[a] Calculated on the basis of maximum number of weeks (nine) on terminal by student from the group.

Table 7.3

Character and Operand Code Count for Five Selected Questions from Modern Mathematics Course Field Trial, Spring 1966

Op Codes	Ques. 1		Ques. 2		Ques. 3		Ques. 4		Ques. 5		Total f for 5 Qus	Total C for 5 Qus
	f*	C**	f	C	f	C	f	C	f	C		
Primary												
rd	1	21									1	21
rdn	1	81									1	81
qu			1	203	1	69	1	304	1	109	4	685
Major												
ca	1	22	2	50	1	41	1	25	1	24	6	162
cb												
wa					1	28					1	28
un	2	150	1	224	1	64	2	197	1	77	7	712
nx	1	16	2	32	2	32	1	16	1	16	7	112
Minor												
ty			2	66	2	249	1	26	1	26	6	367
fn	3	73	2	44	2	44	1	22	1	22	9	205
TOTAL	9	363	10	619	10	527	7	590	6	274	42	2373

*frequency
**Number of characters

The entire question and related materials for each of these sample questions is presented on the following pages. Following each question and related material is a table which shows the attempts which each student made to answer that question.

This field trial was conducted on the 1410 computer located at the Computation Center on Penn State Campus and because of a transition from one system to another, some data which are normally available from student records were not available for this field trial.

Sample Question 1--Modern Mathematics

Sequence No.	Label	Op Code	Argument
06-0300-226	6-45-8	rd	
		fn	slide//12
		fn	wait//10
	6-45-c	qu	Now analyze the table. Is addition in this system commutative?
		nx	
		fn	kw//2
		ca	y es
		un	Check each combination. Then answer the question again.
		un	Addition is commutative in this system. Type yes

Sample Question 1. Slide number 12 is presented to the student and the system waits 10 seconds for the student to examine the slide. The question is typed for the student and the system waits for the student to respond. A stored correct response "yes" will be processed by a keyword (kw) function. Spaces have been used as delimiters in the correct response which segments the word yes into two words, the first consisting of "y" and the second consisting of "es." The keyword function examines for two responses. This procedure allows the author to ignore uppercase or lowercase letters as part of the response. The response will be counted correct whether or not it has been capitalized.

Table 7.4

Student Responses for Sample Question 1
from Modern Mathematics Course
Field Trial, Spring 1966

Student Number	Trial 1	Trial 2	Trial 3
0022	yes		
0023	yes		
0024	no	yes	
0025	no	yes	
0028	yes		
0029	yes		
0030	yes		
0031	yes		
0032	yes	no	yes
0033	yes		

Sample Question 2--Modern Mathematics

Sequence No.	Label	Op Code	Argument
08-0600-010	8-43	qu	After multiplying the sum of the raised fingers by 10 and finding the product of the closed fingers, what two numbers are added when you are using the finger method to solve 6 x 6?
		nx	
		fn	kw//3
		ca	.20. + .16
		ty	Correct.
		nx	
		fn	kw//2
		ca	.20.16
		ty	Yes, 20 is added with 16.
		un	One finger is raised on each hand; 10 (1 + 1) = 20. Four fingers are closed on each hand; 4 x 4 = 16. Therefore we will add 20 + 16. Type 20 + 16.

Sample Question 2. Keyword functions are again used in this question to examine specific elements which should appear in the student's answer without regard to order, spacing, or punctuation. Periods have been used as delimiters to separate the three keywords in the two functions.

Table 7.5

Student Responses for Sample Question 2 from Modern Mathematics Course Field Trial, Spring 1966

Student Number	Trial 1	Trial 2
0022	1 and 1	20 + 16
0024	20 + 16	
0025	20, 16	20 + 16
0028	10 + 16	20 + 16
0029	The product of the raised fingers with the product of the closed fingers.	20 + 16
0030	20 + 16	
0031	20 + 16	
0032	1	20 + 16

Sample Question 3--Modern Mathematics

Sequence No.	Label	Op Code	Argument
09-0730-020		qu	How do you know if a number is divisible by 3?
		nx	
		fn	kw//4
		ca	.sum.digits.divi.3.three
		ty	Yes
		nx	
		fn	kw//2
		wa	.multiple.3
		ty	A number is divisible by 3 if there is a multiple of 3 in the ones place. Consider, however, 42 and 135. Both are divisible by 3, yet there is no multiple of 3 in the ones place. Now answer again.
		un	Consider the sum of its digits. Try again.

Sample Question 3. This question is a very good example of processing free-form responses made by the student. The authors have included five key words in the first ca processed by the preceding keyword function which is seeking four correct words. Four of the five key words must appear in the correct answer without regard to order. Notice that the authors have used only a segment (divi) of the word "division" or "divide" to allow flexibility in the form which the student might use in responding. The authors have also used the numeral "3" or "three" to allow added flexibility in responding. It is interesting to note in Table 7.6 the diversity of responses which have been counted correct by the author and the system.

Table 7.6

Student Responses for Sample Question 3 from Modern Mathematics Course Field Trial, Spring 1966

Student Number	Trial 1	Trial 2	Trial 3
0022	Divide it	If the sum of its digits in an 1 number divisible by 3.	
0023	If the last number is a multiple of Three	If the sum of its digits is a multiple of three	If three divides evenly into the sum of its digits
0024	If a multiple of 3 is in the ones place	If the sum of the digits is divisible by 3	
0025	9,2	Divisible by 3	If the sum is divisible by three
0028	Divide	The sum of its digits is a multiplicand of 3	The sum of its digits is equally divisible by 3
0029	If 3 divides into each number	3 must divide into each digit	Sum must be divisible by 3
0030	Add up the digits and see if they are divisible by 3	The sum of the digits are divisible by 3	
0032	Multiple of three	1	Equal three or multiple
0033	If the sum of its digits equals three	Not equals but is divisible by three	The sum of its digits is divisible by three

Table 7.6 (cont'd.)

Student Responses for Sample Question 3
from Modern Mathematics Course
Field Trial, Spring 1966

Student Number	Trial 4	Trial 5	Trial 6
0025	Sum	The sum of the difigits are divisible by three	Sum of the digits are divisible by three
0029	Sum of digits is divisible by 3		
0032	Multiple of three	Three or multiple	Sum of the digits is divisible by three

Student Number	Trial 7	Trial 8
0032	Sum divided by three	The sum of the digits are divisible by three 3

Sample Question 4--Modern Mathematics

Sequence No.	Label	Op Code	Argument
09-0770-020		qu	What digit which makes the number divisible by 9 can be put in each blank? (Type the missing digits in order, with a comma between each.) 7843__ 30__7 1156__91 811__623
		nx	
		fn	kw//4
		ca	.5.8.4.6
		ty	Good!
		un	The missing digits must make the sum of the digits in each case equal to a number divisible by 9. Try again.
		un	The missing digits are 5, 8, 4, 6. Type this.

Sample Question 4. This question again uses the keyword (kw) function to process the student's responses. It is apparent from Table 7.7 that the program has reasonably good control of student responses. Student 0029 "signed off" when he was presented with this problem the first time and did not attempt the response until he "signed on" the following day.

Table 7.7

Student Responses for Sample Question 4 from Modern Mathematics Course Field Trial, Spring 1966

Student Number	Trial 1	Trial 2	Trial 3
0022	5, 8, 4, 6		
0023	5, 8, 4, 0	I don't understand what I'm am doing wrong	5, 8, 4, 6
0024	5, 8, 4, 6		
0025	5, 8, 4, 6		
0028	2, 2, 1, 0	5, 8, 4, 6	
0029	off	5, 8, 4, 6	
0030	5, 8, 4, 6		
0031	5, 8, 4, 6		
0032	4, 8, 4, 6	5, 8, 4, 6	
0033	3, 8, 4, 6	6, 8, 4, 6	5, 8, 4, 6

Sample Question 5--Modern Mathematics

Sequence No.	Label	Op Code	Argument
11-1020-020		qu	Consider 2/7 x 3/5. Note your procedure as you find the solution. What is 2/7 x 3/5?
		nx	
		fn	kw//3
		ca	.6./.35
		ty	Correct
		un	2/7 x 3/5 = (2 x 3)/(7 x 5) = 6/35. Type 6/35.

Sample Question 5. This question again uses the keyword (kw) function for processing the responses without requiring specific spacing or punctuation. Table 7.8 indicates again that the program has very close control of student responses to this question.

Table 7.8

Student Responses for Sample Question 5 from Modern Mathematics Course Field Trial, Spring 1966

Student Number	Trial 1	Trial 2
0022	6/35	
0023	6/35	
0025	31/35	6/35
0028	6/35	
0029	5/35	6/35
0030	6/35	
0031	210/35	6/35
0032	31/35	6/35
0033	6/35	

CHAPTER VIII

SUMMARY OF PRELIMINARY STUDIES AND FIELD TRIALS

During the course of the project, approximately 97 Penn State students completed sections of the four CAI courses. The total group of students may be divided into two subgroups of 30 and 67. The computer time used for student instruction amounted to approximately 576 hours during the field trial.

The first subgroup was comprised of those students who experienced an entire CAI sequence for academic credit during the field trial of the four courses. The details of the field trial are reported in chapters IV (Audiology), V (Management Accounting), VI (Engineering Economics), and VII (Modern Mathematics). However, the total use of the Laboratory for the field trial for all four courses is summarized in Table 8.1.

The other subgroup of 67 students were involved with the project before the completion of the four courses.

Forty-seven students were used to help test courses early in the investigation prior to the development of achievement criterion measures. For this group, the variables available for analysis were

1. Self-report ratings of reactions to CAI
2. Student errors in CAI courses
3. Rate or speed of performance on course material
4. Scholastic Aptitude Test scores (SAT)

Table 8.1

Time Spent on Computer Terminals by Students in the CAI Groups for the Field Trial of Four College Courses

Course	No. of Students	Total Time hrs/mins		Maximum Time hrs/mins		Minimum Time hrs/mins		Average hrs/mins	
Speech Pathology and Audiology	4	63	48	19	24	11	49	15	57
Management Accounting	10	181	0	26	8	9	10	18	6
Engineering Economics	6	71	54	17	6	9	23	12	0
Modern Mathematics	10	259	38	29	41	17	10	25	58
Totals	30	576	20	--	--	--	--	18	25

5. Cumulative grade point average
6. Scores on the Penn State entrance examination battery and various subtests
7. Scores on the Bernreuter Personality Inventory administered to entering freshmen at Penn State

For the second group of 20 students, measures of achievement of course content and retention were obtained in addition to the above variables.

Reactions of Students to CAI

Of the first 47 students, 18 worked in audiology, 21 in cost accounting, 7 in modern mathematics, and 1 in engineering economics. The results fall into three general categories: 1) mean student self-reports of reactions to CAI, 2) selected correlations among a number of student variables and performance in CAI, and 3) impressions obtained from guiding students through the courses and from informal interviews with students following their experience with CAI. The results should be regarded as tentative and suggestive of hypotheses for further study under highly controlled conditions. The 47 students were the first pilot group to test the CAI courses. They are not a random sample of college students, nor were they assigned at random to the four courses. Frequently the students were used to help "debug" the courses, and problems were encountered by the student which would not ordinarily occur with a finished course. In addition, these early results are primarily of a correlational and descriptive nature with the accompanying difficulties of determining the direction of causation. In spite of the above limitations, there appear to be some meaningful differences among the scales of the student reaction inventory, and some clusters of intercorrelations which "make sense" and support our subjective impressions.

Following his first session of CAI, each student completed a Student Reaction Inventory consisting of a number of scales modeled after the Semantic Differential (Osgood et al, 1957). The student reaction inventory developed for this investigation appears in Appendix C.1. The extremes of each scale are defined by pairs of bi-polar adjectives such as good-bad, dull-interesting, tense-relaxed. Thirty-one students completed the reaction inventory (the first 16 students were taught prior to the development of this device).

A profile of the mean ratings on twelve attitude scales was constructed for the total group and separately for each course. This profile is shown in Figure 3. An examination of the high points on the profile of student attitudes toward CAI indicates that students found the experience highly interesting, good, fair, valuable, and active, and that the students reported being able to give the machine more attention than a traditional classroom lecture.

That students react favorably to a new and novel instructional technique such as CAI is reassuring, but not particularly surprising. The low points in the profile of student reactions may be of greater importance in pointing the way to improvements in the instructional system and toward new instructional strategies. The three lowest points in the profile indicated that the students reported being relatively tense as opposed to relaxed, they reported the program to be inflexible, and that they missed opportunities for discussion. Fifty-four per cent of the sample reported being "slightly tense" during the first session of CAI.

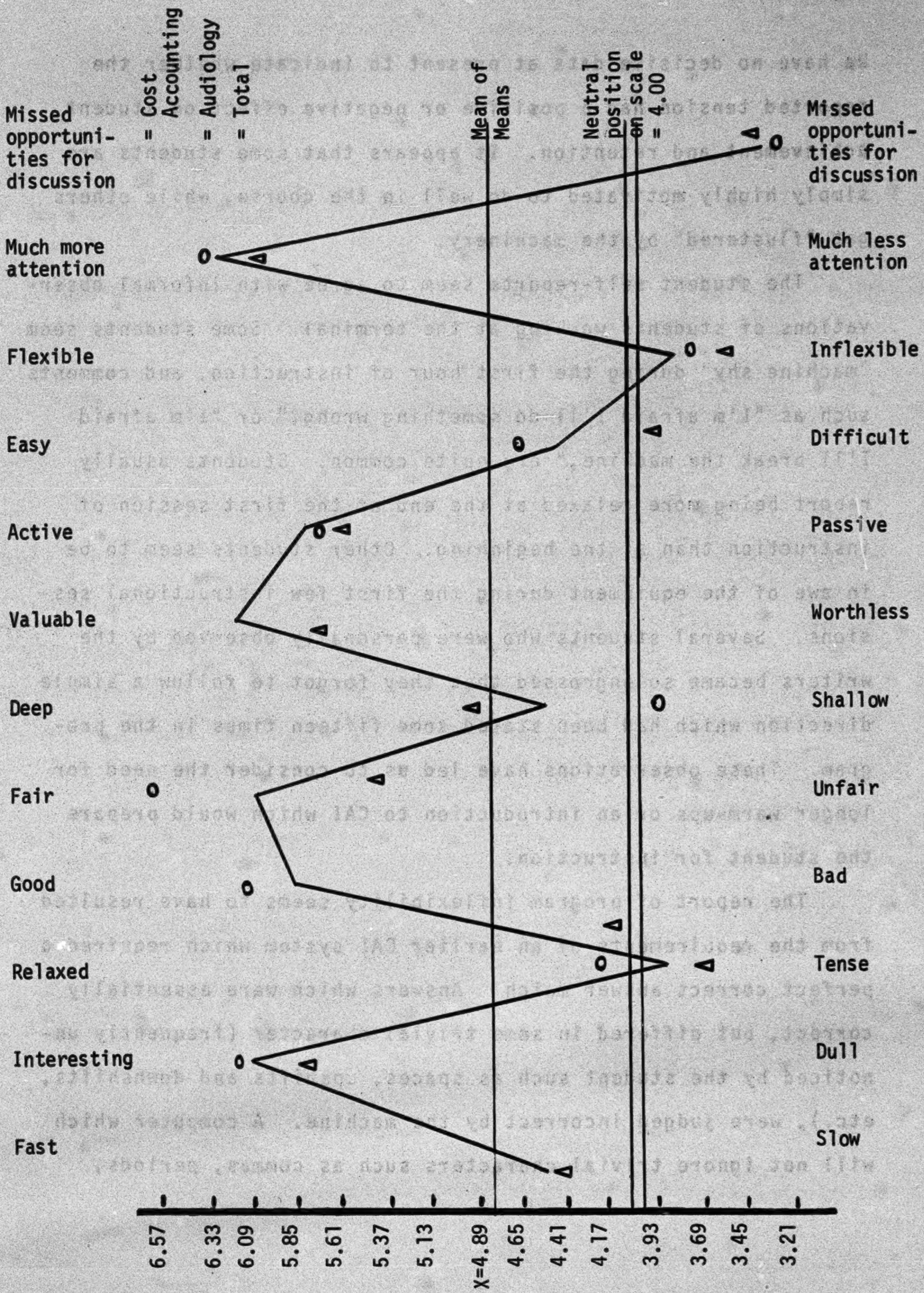

Fig. 3. Profile of Mean Student Reactions to CAI

We have no decisive data at present to indicate whether the reported tension had a positive or negative effect on student achievement and retention. It appears that some students are simply highly motivated to do well in the course, while others get "flustered" by the machinery.

The student self-reports seem to agree with informal observations of students working at the terminal. Some students seem "machine shy" during the first hour of instruction, and comments such as "I'm afraid I'll do something wrong," or "I'm afraid I'll break the machine," are quite common. Students usually report being more relaxed at the end of the first session of instruction than at the beginning. Other students seem to be in awe of the equipment during the first few instructional sessions. Several students who were personally observed by the writers became so engrossed that they forgot to follow a simple direction which had been stated some fifteen times in the program. These observations have led us to consider the need for longer warm-ups or an introduction to CAI which would prepare the student for instruction.

The report of program inflexibility seems to have resulted from the requirements of an earlier CAI system which required a perfect correct answer match. Answers which were essentially correct, but differed in some trivial character (frequently unnoticed by the student such as spaces, upshifts and downshifts, etc.), were judged incorrect by the machine. A computer which will not ignore trivial characters such as commas, periods, spaces, etc., and correctly evaluate a correct answer is judged inflexible by students. These reports emphasize the need for partial-answer processing in CAI systems. It is anticipated that the ratings of future groups of students will indicate greater course flexibility as more of the functions permitting partial-answer processing are incorporated into the courses.

Students also rated the machinery as quite "fast." This reaction raises the question of rapidity of CAI. CAI frequently appears to qualify as an instance of massed practice. Although the system is in theory student-paced, the immediate presentation of the next question following a correct answer tends to "force feed" the student. A study is presently underway to investigate the effects of student-controlled pauses in the presentation of the course. Unfilled delays might provide time for students to process information and to rehearse their responses, and might be especially valuable following the correction of an error.

Correlations among Selected Student Variables, Reactions to CAI and CAI Performance Variables

A missing data correlational analysis of a matrix of variables including student errors, rate of performance, SAT scores, cumulative grade point average, Bernreuter personality scales administered to all entering freshmen at Penn State, student reactions to CAI, etc., was prepared. The analysis was performed for the total group of 47 students and separately for students in audiology and cost accounting. Keeping in mind the difficulties of a posteriori "data snooping," the writers examined the matrix in an attempt to find nonchance, meaningful clusters of correlation coefficients. The results reported here are those which in the judgment of the writers seemed to tie together.

Although there are probably few individuals working in CAI who question the educational advantages of partial-answer processing, some of the present results make quite clear the problem of the nonmatched correct answer from the student's viewpoint. (The present data were obtained prior to the availability of partial-answer processing.) In scoring the student's record for errors, it was necessary to distinguish between legitimate content errors and what were called correct answers, entered in wrong form, which were regarded as incorrect by the computer. The mean per cent content errors based on the students' total number of responses for all courses was 20 per cent while the mean per cent correct answers entered in wrong form was 17 per cent. The correlations between the two types of errors were positive and significant at less than the .001 level for the total group and within each course. This correlation reflects the fact that the student types in the correct answer in wrong form, tries the same answer once or twice more just for good measure, and then discards his original correct answer for an incorrect response, thus making a content error. Some persistent students may type in their original correct answer again and again. When numbers of questions were used as the base for computing the percentage of errors, several students exceeded 100 per cent. An additional problem is that these persistent students may be the self-sufficient students, and the system is negatively reinforcing self-sufficient behaviors. The Bernreuter Stability and Self-sufficiency scales correlated significantly and positively with the percentage of correct answers entered in wrong form (.43 and .56 respectively). The manual for the Bernreuter describes the measure of self-sufficiency as follows: "Persons scoring high on this scale prefer to be alone, rarely ask for sympathy or encouragement, and tend to ignore the advice of others. Those scoring low dislike solitude and often seek advice and encouragement."

Although the problem of correct answers in wrong form can be minimized by specific instructions to students at the beginning of a course or by inserting additional correct answers, some wrong form errors result from typing habits and poor punctuation. A correlation of .35 ($P < .05$) between the number of lines of program covered by a student per hour and a Punctuation subtest score on the Penn State entrance examination was obtained. Furthermore, a negative correlation of -.26 approaching significance between Punctuation scores and percentage of wrong form errors was also obtained. Recently, a small group of eight students was administered an achievement test after completing a section of audiology. Just one or two "bugs" in the program, particularly of the correct response-wrong form type, seemed to produce much interference and large decrements in student learning. These results emphasize the importance of exposing students to a smooth-running CAI course. The partial-answer functions described earlier in Appendix A.1 alleviated the problem of requiring a student to match an anticipated answer exactly.

The correlations in Table 8.2 (shown for the total group and cost accounting in parentheses) generally indicate that students having lower cumulative grade points and scoring lower on the entrance battery tended to rate the course and machine as "fast." The correlations of several subtests from the Penn State entrance battery with percentage of content errors are suggestive of a similar negative relationship, although they are less consistent. These data are indicative of the importance of the speed factor and suggest that courses employing optional delays, optional review, and optional remedial work would be beneficial for some students.

Performance of High and Low Aptitude Students in CAI

The second pilot study employed a sample of 20 volunteer students from introductory educational psychology classes. The sample consisted of 12 high aptitude Ss and 8 low aptitude Ss as measured by the Scholastic Aptitude Test. High and low aptitude was defined as the upper and lower 25 per cent of the distribution of verbal SAT scores. The test had been administered to the students upon entrance to the University. The performance of this group of Ss was studied in a much more systematic manner than that of the initial group of 47 students.

Each subject was scheduled for three sessions at the CAI Laboratory. During the first session, the S was given a warm-up at the instructional terminal in the early afternoon of the day he was scheduled to participate in the experiment. Previous experience with students suggested that some warm-up to give the student practice operating the instructional terminal was extremely important. The student was allowed to warm-up on a short section of the modern mathematics course on elementary set theory. During this period a graduate assistant worked with the student at the terminal to clear up any questions or problems he might encounter. A set of directions was also read to the student explaining the general nature of the experiment. Immediately following the warm-up period, the student was administered a pretest to measure his previous knowledge of the subject matter area in which he would be given instruction that same evening. Later the same day at approximately 6:30 p.m., the student returned for instruction via CAI on a section of the modern mathematics course designed to teach number systems with bases other than ten. Portions of the modern mathematics course are shown in Appendix G.4. Immediately following instruction at the terminal, the student was given an alternate form of the pretest designed to measure his achievement of course

Table 8.2

Correlations among Some Cognitive Measures, Reactions to the Speed of CAI, and Percentage of Content Errors (n = 21)

	Penn State Entrance Exam Subtests (Moore-Caster)					
	C.C.P.A.	Vocab.	Paragraph Reading	Spelling	Punc.	Total
Rating:						
Course Fast	-.15 (-.50)**	-.27 (-.51)**	-.33 (-.29)	-.14 (-.43)*	-.08 (-.12)	-.30 (-.37)
Machine Fast	-.35* (-.69)**	-.37* (-.44)*	-.37* (-.49)*	-.31 (-.46)*	-.11 (-.24)	-.32 (-.38)
Per cent Content Errors	.13 (-.12)	-.20 (-.36)	-.11 (-.27)	.06 (-.48)**	.08 (-.30)	-.26 (-.45)*

* $P < .10$
** $P < .05$

content (hereafter referred to as posttest 1), and was asked to fill out the Student Reaction Inventory. The student returned exactly one week later for session three and at that time took another form of the achievement test (posttest 2) as a measure of retention. Due to an error in procedure, some students were administered posttest 1 a second time while others were given the pretest again as the posttest 2 measure. The original intent was to use the pretest as the delayed retention measure to minimize direct recall of responses given to items in the test. An examination of the students given the different forms of the achievement test as posttest 2 shows no differences in their performance as a function of the form of the test used.

Reliability of the Achievement Measures

As mentioned previously, an important aspect of research on CAI is the development of good achievement tests and other criterion measures to evaluate the outcome of such instruction. Several short achievement tests were developed in the present project: one to measure achievement in the audiology course, and two alternate forms of a test to measure achievement in the use of number systems with bases other than ten. Each form of the modern mathematics test was 23 items in length. Reliability of the test was evaluated by means of the Hoyt analysis of variance technique (Hoyt, 1941).

The analysis of variance summary for the sample of 20 students on Form B is shown in Table 8.3. The reliability of the test as estimated by the formula $r_{tt} = I - \frac{\text{M.S. residual}}{\text{M.S. between } \underline{\text{Ss}}}$ is shown directly beneath the table to be .93.

Since the subjects in the present sample were selected as extreme high and low aptitude groups, the possibility exists that the above reliability coefficient is spuriously high due to the exclusion of students of average aptitude. In order to check this possibility, separate estimates of reliability were obtained within the high aptitude and low aptitude groups. If the range of scores on the achievement test had been seriously inflated by using extreme aptitude groups, one would expect the reliabilities computed separately within the restricted range of high and low aptitude groups to be substantially lower than the reliability for the entire group.

Tables 8.4 and 8.5 show the analyses of variance estimates of reliability for the 12 high aptitude students and 8 low aptitude students respectively. As can be seen from the tables, the reliabilities were .92 and .94 for the high and low SAT groups respectively indicating that the use of extreme groups had no effect on the reliability estimate for the achievement test.

Table 8.3

Analysis of Variance Reliability of Form B
of the Modern Mathematics Achievement Test
for the Total Group of 20 Students

Source	SS	df	MS
Between Ss	39.52	19	2.08
Within Ss	67.65	440	
Items	11.17	22	.51
Residual	56.48	418	.14
		459	

$$r_{tt} = 1 - \frac{.14}{2.08} = .93$$

Table 8.4

Analysis of Variance Reliability of Form B of the Modern Mathematics Achievement Test for the Group of 12 High SAT Students

Source	SS	df	MS
Between Ss	18.98	11	1.73
Within Ss	37.83	264	
Items	5.98	22	.27
Residual	31.85	242	.13

$$r_{tt} = 1 - \frac{.13}{1.73} = .92$$

Table 8.5

Analysis of Variance Reliability of Form B of the Modern Mathematics Achievement Test for the Group of 8 Low SAT Students

Source	SS	df	MS
Between Ss	16.15	7	2.31
Within Ss	29.83	176	
Items	9.98	22	.45
Residual	19.85	154	.13

$$r_{tt} = 1 - \frac{.13}{2.31} = .94$$

The prior reliabilities reflect a high level of internal consistency of the test. Some evidence on the stability of performance on the modern mathematics achievement test is available from the correlation between the posttest 1 and posttest 2 administrations over a one week interval. The latter correlation was .93. Owing to a highly restricted range of scores on the pretest (students showed very little prior knowledge of number systems with bases other than ten), no meaningful correlations between the pre- and posttests could be computed.

Results

The results are reported in the form of two analyses. The first analysis shown in Table 8.6 shows t tests comparing the means of the high versus low SAT groups on a number of performance and attitude ratings. The reader should note that the series of t tests reported in Table 8.6 is not the most ideal statistical analysis for these data since some of the dependent variables are correlated and thus provide partially redundant information. Owing to the small samples of subjects and the preliminary nature of the data, appropriate multivariate analyses were considered uneconomical at the present time. A correlational analysis was also computed showing some of the same relationships shown in the table of t tests and, in addition, relationships between a number of other variables. The results of the correlational analysis are shown in tables 8.7 and 8.8.

The results of the t test analysis generally indicate that the high aptitude group performed better and had more positive attitudes toward CAI than the low aptitude group. Although the groups differed significantly on the pretest, the mean performance of both groups was less than one item correct out of 23. It can be concluded that the students in the sample had very little prior information about number systems with bases other than ten. Although the posttest achievement scores and other performance measures were not significantly different for the two groups, every difference was in the expected direction. The high SAT group had higher mean achievement posttest scores and lower mean number of errors, less time to complete the material, and fewer remedial questions than the low SAT group. In general, the high aptitude subjects evidenced more positive attitudes towards CAI than the low aptitude subjects. The mean ratings for the high SAT Ss were more positive than those of the low aptitude Ss on 12 of the 13 scales. The statistically significant differences indicate that the high SAT group had higher means than the low group on the scales Bad-Good, Unfair-Fair, and Difficult-Easy (as might be expected). The low group also reported that they more frequently missed opportunities for discussion during instruction at the CAI teaching terminal. The most likely interpretation of the differences in attitudes of the high and low aptitude groups is that poorer performance produces more negative attitudes toward the instructional method

Table 8.6

Comparisons of High and Low Aptitude Groups (as Measured by the SAT) on CAI Attitude and Performance Variables

Variable	Low SAT (n=8) X	High SAT (n=12) X	t	P
Pretest	0.12	0.83	+ 2.20	.05
Posttest 1	12.0	16.50	+ 1.49	
Posttest 2	13.6	15.9	+ .70	
SAT V	420.9	607.5	+10.90	.001
SAT M	479.3	541.5	+ 1.81	.10
Ratings of Course:				
Fast	3.9	4.0	+ .14	
Interesting	5.2	5.3	+ .10	
Relaxed	3.6	4.8	+ 1.08	
Good	3.5	5.2	+ 2.14	.05
Fair	3.8	5.9	+ 2.42	.05
Deep	4.8	4.3	.51	
Valuable	4.4	5.1	+ .80	
Active	4.5	4.9	+ .43	
Easy	2.2	4.4	+ 2.85	.02
Flexible	3.2	4.3	+ 1.53	
Machine Fast	4.6	5.3	+ .67	
More attention to machine	4.0	6.1	+ 1.66	
Did not miss opportunities for discussion	3.1	5.5	+ 2.21	.05
Total Errors	35.0	24.2	1.36	
Content Errors	30.6	21.2	1.37	
Form Errors	4.4	3.0	1.08	
Mean Time	206.1	179.5	1.13	
Mean No. Remedial Questions	53.5	48.9	.45	

regardless of what method is being used. Since aptitude correlates positively with performance in the course, the differences in mean ratings cannot be attributed to aptitude alone. Results from the correlational analysis support the interpretation that poor performance produced the negative rating rather than the other way around.

A comparison of the mean posttest 1 and delayed posttest 2 scores indicates that no forgetting took place over the one week interval. The total group mean for posttest 1 was 14.7, while the mean for the one week delayed test was 15.0. The retention evidenced after one week is probably a function of the nature of the learning task used in the study. Manipulating number systems with bases other than ten involves learning a set of principles which, once mastered, are probably not easily forgotten. In fact, the principles learned are the same principles used implicitly by all students in working with the base ten or decimal system. Once the student learns to apply the rules with number systems having bases other than ten, his vast experience with the decimal system most likely facilitates retention.

Table 8.7 shows the matrix of intercorrelations for the Scholastic Aptitude Test Scores and the CAI performance measures. It should be remembered that the use of extreme groups on the aptitude measure would tend to inflate correlations over what would be obtained if the entire range of aptitude scores had been used. The extreme high and low aptitude groups used in

Table 8.7

Correlations Among Scholastic Aptitude Test (SAT)
and CAI Performance Measures
(n=20)*

	SAT U	SAT M	Posttest 2	Delayed Posttest 2	Errors	Time	Remedial Questions
Verbal SAT		.50	.45	.24	-.41	-.10	-.18
Math. SAT			.47	.51	-.37	-.07	-.18
Posttest 1				.93	-.93	-.49	-.79
Delayed Posttest 2					-.87	-.50	-.77
Errors made in program						.55	.81
Time to complete course							.55

$*r_{.05} = .44$

$r_{.01} = .56$

the present preliminary analysis were selected as part of a larger experiment designed to investigate interactions between student ability and course sequencing variables. Although the present correlations may be spuriously high, they provide important preliminary information concerning the nature of the relationships between the variables.

As can be seen in Table 8.7, correlations between the SAT scores and the two achievement posttest scores ranged from .24 to .51. The correlations of the verbal and mathematical SAT scores with the number of errors made in the program were -.41 and -.37 respectively. These correlations fall within the range of magnitude of correlations usually obtained between measures of scholastic aptitude and school achievement. It is of interest to note that one of the objectives of computer-assisted instruction is to minimize the correlation between student aptitude and the outcomes of instruction by adapting the instruction to the abilities of the learner. Thus, if all students begin to approximate maximum achievement as measured by a criterion test, the correlation between aptitude and achievement would necessarily be decreased. Whether a truly adaptive instructional program can bring all college students to approximately the same level of achievement still remains to be demonstrated.

Another rather revealing set of correlations were those of the achievement criterion tests with errors and the number of remedial questions encountered by the student. The correlations of errors with posttests 1 and 2 were -.93 and -.87 respectively, while the correlations between posttests 1 and 2 and errors is surprisingly high in view of the fact that the modern mathematics program included approximately fifty per cent remedial branches designed to clear up student errors. If the remedial sections of the course had been serving their proper function, student errors made in the program would have been corrected by the remedial branch and the student should not have responded with the same errors on the posttest measure of achievement. If the remedial sections had in fact been correcting student errors, one would have expected a somewhat lower correlation between errors made in the program and errors made on the achievement posttest. The correlation of -.93 suggests that the student who was confused during the actual instruction remained confused on the achievement posttest. The above interpretation is based on correlational data and small samples and is therefore highly tentative; however, the results do call attention to the problems of evaluating the effectiveness of remedial branching programs for student learning. In the future we plan to make more specific comparisons between course programs with and without remedial instruction and comparisons of the effects of different types of remedial instruction.

Table 8.8 shows the correlations between the ratings of attitude towards CAI and the SAT and CAI performance measures. As was seen in the earlier analysis, in general, the higher the SAT and achievement in the course the more positive the reaction to CAI. The fewer errors and number of remedial questions encountered, and the shorter the time taken to complete the program, the more positive the attitude toward CAI. Although it is difficult to interpret these relationships, it was probable that the student reacted primarily to his own performance in CAI rather than to his liking of CAI as a method of instruction. Several partial correlations were computed between the SAT scores and the Good-Bad rating holding posttest performance constant.

When student performance is held constant, the correlations between the SAT scores and the Bad-Good rating decrease and become nonsignificant. In the case of the verbal SAT, the correlation dropped from .38 to .17, while for mathematical SAT the correlation dropped from .51 to .34.

Problems in interpretation of self-report data are not uncommon in many different areas of research. The present judgment of the investigators is that the utility of the Reaction Inventory has probably been exhausted. Since self-reports are inexorably entwined with a host of complex effects, it is frequently impossible to determine precisely what the student's self-report is measuring. As demonstrated in the present study, the self-report, rather than measuring the student's attitude toward a method of instruction as such, appears to be measuring his reaction to his own performance. If this is the case, the self-report is providing very little new information over that of the performance measures. The self-report measure was employed in the present investigation in lieu of the development of more adequate criteria. As such, it served its purpose by suggesting hypotheses for further study.

The results of Table 8.8 also show that the student's ratings on the Shallow-Deep scale and on the Difficult-Easy scale appear to reflect his perception of the difficulty of the course. Both scales appear to correlate with aptitude and performance in the expected directions.

Several findings obtained with the second sample of students bear on some earlier results obtained with the initial group of 47 students. The reader will recall that a fairly large percentage of students reported being slightly tense during the first hour of instruction in the first sample. In analyzing the data for the second sample, essentially zero correlations were obtained between performance in CAI and the Tense-Relaxed rating. So far as this small sample of students is concerned, it appears that whatever the student is reflecting on this scale does not relate to his performance in the course. This finding illustrates another common difficulty with self-report data: what the student says he does and what he does are frequently two different things.

The correlations of the CAI performance measures with the Slow-Fast rating simply reflects the student's perception of his rate of performance in the course. Thus, the students achieving higher scores on the posttests, making fewer errors in the course and taking less time to finish the material, tend to rate the course as fast compared to students scoring lower on the posttests and making more errors.

One finding of considerable importance relates to results obtained in the initial sample of students. The number of correct answers entered in wrong form was found to correlate -.80 with performance on the achievement posttest in the second sample. It was tentatively concluded in the earlier study that

Table 8.8

Correlations Among Scholastic Aptitude (SAT), CAI Performance Measures, and Attitudes Toward CAI (n=20)*

	Ratings					
	Course "Fast"	Good	Fair	Deep	Valuable	Easy
Verbal SAT	-.18	.38	.46	-.39	.17	.37
Math. SAT	.06	.51	.09	-.68	.31	.26
Posttest 1	.44	.55	.00	-.47	.32	.45
Delayed Posttest 2	.58	.49	-.16	-.47	.34	.44
Errors	-.47	-.46	-.06	.34	-.20	-.39
Time	-.51	-.42	-.13	.36	.11	-.49
Remedial Questions	-.53	-.29	.17	.37	-.22	-.30

$^{*}r_{.05} = .44$

$r_{.01} = .46$

"bugs" encountered by the student in the course or correct answers entered in wrong form tended to seriously interfere with student learning. The results for the second sample tend to support this conclusion. The occurrence of wrong form errors tends to encourage content errors (e.g., the two are correlated .79) which in turn tends to produce poor posttest performance (e.g., -.80). These data simply further emphasize the importance of partial-answer processing of student responses so that an answer which is correct in its essential elements is accepted as correct by the computer.

Finally, although the numbers in each group are small, it is of interest to compare the distributions of posttest performance for the two high and low aptitude groups. These distributions are shown in Table 8.9. Perhaps the most striking observation of student performance in CAI is the tremendous variability in performance and the large overlap of the distributions of high and low aptitude Ss. Clearly the majority of Ss in both groups demonstrated considerable learning on the achievement posttest. Only three Ss (one student in the high group) appeared to exhibit little or no learning on the posttest. Nevertheless, the fact that even three students of college-level ability seem to exhibit no learning after instruction designed to adapt to individual differences by providing the necessary remedial work is the challenge still facing researchers interested in the problems of student learning in adaptive instructional systems.

Table 8.9

Distributions of Posttest Achievement Scores of High and Low Aptitude Groups

Scores	Low SAT	High SAT
21-22		5
19-20	1	2
18-19	1	
16-17	2	1
14-15	1	
12-13		2
10-11		1
8-9	1	
6-7		
4-5		
2-3	1	1
0-1	1	
	8	12

CHAPTER IX

DEMONSTRATION AND DISSEMINATION

One major purpose of the present project was to provide demonstrations to educators of a functioning prototype of a CAI system and to disseminate information pertaining to our experience with CAI. This objective was based on the assumption that implementation of educational innovations is most likely to occur as a result of live "hands on" demonstrations given to educators. To make some inroads in the problem of information dissemination, the project undertook a large number of live demonstrations of CAI, produced a video-tape demonstration and a 16mm sound, color film on CAI, prepared several short demonstration courses illustrating different aspects of CAI, presented and published several research reports of preliminary results with CAI, and conducted a conference on the application of CAI to the in-service preparation of teachers. Each of these activities is summarized briefly.

Our guestbook contains 981 names of visitors to the CAI Laboratory at Penn State, but it is estimated that over 500 individuals have seen a live demonstration of CAI at the Laboratory. These individuals possessed many different backgrounds of experiences such as educator, psychologist, State Director of Vocational Education, writer, Director of Teacher Education, Professor of Engineering, Professor of Mathematics, physiologist, sociologist, counselor, military officer, and newspaperman. Professional educators from Denmark, Hong Kong, France, Sweden, Australia, Bulgaria, China, Germany, Sudan, and many other western nations have been among our most interested visitors. Many of the demonstrations have promoted much stimulating discussion concerning the potentials of CAI in a variety of educational situations.

In addition to the live demonstrations, the writers in cooperation with the Instructional Television Services of The Pennsylvania State University, produced a video-tape demonstration of a student working at the CAI teaching terminal. This video-tape is shown regularly to students in the introductory educational psychology courses which prepare several hundred potential teachers per term. The taped demonstration was also shown to a conference in continuing education and to a group at the United States Office of Education in Washington.

During the summer of 1965 the instructor of the introductory educational psychology course invited Professor Hall to participate in the preparation of a 75-minute video taped discussion on programmed instruction and particularly on CAI. The program developed the historic and scientific progress of programmed instruction and utilization procedures for teachers with particular emphasis on CAI which included demonstration of a CAI course incorporating all of the available functions, taped recorded messages, and projected images from the slide projector.

Several short demonstration courses have been prepared to illustrate various capabilities of CAI to the visitor. The courses may be briefly described as follows:

md1 and md2 -	a short segment of material covering several elementary concepts of educational measurement. The demonstration illustrates various capabilities of the slide projector and tape recorder units. The course also includes a five question quiz related to the concepts taught. The student's score is typed for him, and he is told specifically which questions he missed on the quiz. The program then branches to a remedial section, and the student is given specific information on why the specific answer he chose for each missed question was wrong and in addition the correct answer.
spa-430x -	The first chapter adapted from the course - speech pathology and audiology, which is designed to teach students the anatomical parts of the outer, middle, and inner ear. This chapter provides computer branching decisions based upon the student's prior knowledge about certain segments, the student's accumulated responses to previous material, and the student's performance on quizzes throughout the course.

The following papers have been presented reporting preliminary findings of the present CAI project:

Wodtke, Kenneth H. and Mitzel, H. E. Some preliminary results on the reactions of students to computer-assisted instruction. A paper presented at the IBM Conference on Computer Assisted Instruction, T. J. Watson Research Center, Yorktown Heights, N. Y., February 2, 1965.

Wodtke, Kenneth H., Mitzel, H. E., and Brown, B. R. Some preliminary results on the reactions of students to computer-assisted instruction. A paper presented at the Pennsylvania Educational Research Association, University of Pittsburgh, April, 1965.

Wodtke, K. H., Mitzel, H. E., and Brown, B. R. Some preliminary results on the reactions of students to computer-assisted instruction. Proceedings of the 73rd Annual Convention of the American Psychological Association, 1965. Paper was read at the 1965 APA meeting.

Wodtke, Kenneth H. On the assessment of retention effects in educational experiments, November 1965. (Revised February 1966) Presented at AERA on February 15, 1966.

Wodtke, K. H. Computer Assisted Instruction: A simulated tutorial approach. Paper presented to the National Society of College Teachers in Education, Chicago, Illinois, February, 1966.

Wodtke, K. H. A symposium on the topic computer assistance for research on instruction at the American Educational Research Association convention, Chicago, Illinois, February, 1966.

Wodtke, K. H. and Gilman, D. A. Some comments on the efficiency of the typewriter interface in computer-assisted instruction at the high school and college levels. A paper presented at the Annual Convention of the Association of Educational Data Systems, Philadelphia, Pennsylvania, May 1966.

Mitzel, Harold E. Five major barriers to the development of computer-assisted instruction. August 1966. Remarks prepared for American Management Association Meeting, Americana Hotel, New York City, August 12, 1966.

Wodtke, Kenneth H. Educational requirements for a student-subject matter interface. Paper presented at Spring Joint Computer Conference, Atlantic City, New Jersey, April 19, 1967.

Hall, Keith A., Adams, Marilyn, and Tardibuono, J. Cueing and feedback in computer-assisted instruction. Paper presented at NEA National Convention, Department of A-V Instruction, Atlantic City, New Jersey, April 5, 1967.

Wodtke, K. H. Some perspectives on computer-assisted instruction. Paper presented to the Pennsylvania Educational Research Association, Bucknell University, May 19, 1967.

Mitzel, Harold E. Computer assisted instruction - origins, definitions, and growing pains. Paper presented to the American Society for Engineering Education Annual Meeting, Michigan State University, East Lansing, Michigan, June 21, 1967.

A conference was held at Penn State on April 6, 1965, to discuss the application of computer-assisted instruction to in-service preparation of Pennsylvania teachers of modern mathematics. A current problem in the area of mathematics instruction is that of updating the preparation of teachers in the "new mathematics." Existing in-service preparation methods are slow and frequently only reach a small percentage of teachers. During the above conference, members of the Penn State CAI project discussed with educators from the Pennsylvania Department of Public Instruction the possibilities of providing such instruction by means of remote CAI teaching stations placed at strategic locations throughout the state. Although there are a number of problems still to be worked out concerning the practical application of CAI, it was the general impression of the conference that such an application was feasible.

In January 1967 a one-day conference for superintendents and principals was held in Williamsport, Pennsylvania, at which time the research conducted by the CAI staff and the use and potential of CAI were discussed under the direction of Professor Riedesel and Miss Suydam of the CAI staff. This conference summarized a CAI project which was conducted during the fall, 1966, by the Williamsport Area School District sponsored by the

U. S. Office of Education under Title III of the Elementary and Secondary Education Act. The IBM T. J. Watson Research Center at Yorktown Heights, New York, provided full-time computer service for the forty elementary school teachers of mathematics who participated in the in-service "hands-on" terminal presentation of the modern mathematics course.

A second conference on computer-assisted instruction, sponsored by the Office of Naval Research, was held at the Conference Center of the Penn State Campus. CAI staff members, including Professors Mitzel, Hall and Wodtke, made presentations to an audience of 67 professionals interested and involved with programed learning and specifically computer-assisted instruction. All members attending this invitational conference were provided time for a live hands-on demonstration at the CAI terminals and a visit to the Computation Center at Penn State.

A number of off-campus live demonstrations have been arranged and conducted by the Penn State staff. The first off-campus demonstration occurred on October 30 through November 2, 1965, at the American Speech and Hearing Association (ASHA) Convention in the Sherman Hotel in Chicago. A display area, 9 feet by 20 feet, was constructed and contained display panels of information about computer-assisted instruction. In addition to this exhibit, a brochure was printed and distributed to interested visitors in the exhibition hall. Professors Mitzel (Project Director) and Siegenthaler (course author for speech pathology and audiology) and Mr. Jeffrey Katzer (graduate assistant to

Dr. Siegenthaler) represented Penn State and conducted the demonstrations at the exhibit. A closed circuit television system with a video-tape recorder was used as an integral part of the exhibit. During those times when computer service was not available, a video-tape recording of a CAI demonstration especially prepared for this convention was shown on a closed circuit system.

From November 30 through December 2, Penn State again exhibited the audiology course taught by CAI at the Fall Joint Computer Conference in Las Vegas, Nevada. Professor Hall, of the Penn State Staff, conducted this demonstration which was housed in a special exhibit area entitled "Computer Dimensions in Learning." Although the large display material was not used for this conference, the closed circuit video-tape system and the on-line audiology course were used. During the course of the conference, six organized tours of approximately thirty people each were conducted through this special exhibit area. At that time, an opportunity was provided for each exhibitor to explain and describe to the group their efforts in utilizing computers for instructional purposes.

The American Educational Research Association (AERA) held their annual convention at the Pick Congress Hotel in Chicago, Illinois, from February 17 through February 19, 1966. The Penn State CAI Laboratory was invited to provide an educational display for the convention. This was the first exhibit of its type that has been shown at an AERA convention. Again the large wall panels and the complete exhibit were trucked to Chicago for this exhibition; the closed circuit video-tape recording equipment was used on a standby basis only. The Penn State Computation Center and the IBM T. J. Watson Research Center at Yorktown Heights, New York, were able to provide us with full-time computer service for this convention. This was the first large-scale utilization of the Penn State Computation Center for CAI purposes and our experience was most gratifying. In addition to our closed circuit video-tape recording equipment, we had a small camera mounted above the CAI terminal so that the material being typed for the student could be seen by a large group of observers on a television monitor which was part of the exhibit. The staff representing the CAI Laboratory for this exhibit were Professors Bjorkquist, Hall, Johnson, Mitzel, Siegenthaler, and Wodtke; Mr. Jeffrey Katzer also participated.

The American Personnel and Guidance Association held its annual convention at the Municipal Auditorium in Dallas, Texas, from March 19 through March 23, 1967. It was estimated that approximately two thousand members viewed the CAI exhibit which consisted of on-line course segment presentation. During the times when computer service was not available, a continuous loop slide and tape presentation was in operation. The staff representing the CAI Laboratory for this exhibit were Professors Impellitteri, and Campbell; Mr. Scott Kostenbauder also participated in the presentation of this demonstration.

From April 6 through April 8, 1967, Penn State again exhibited the audiology course taught by CAI at the Pennsylvania Speech and Hearing Association annual meeting in Pittsburgh, Pennsylvania. The complete display set-up was used for this presentation, which was conducted by Professors Mitzel and Siegenthaler, with Messrs. Kenneth Getschow and James Stauffer assisting.

Other dissemination activities have also been undertaken by the staff members of the CAI Laboratory. Professor Cramer, author of the CAI introductory management accounting course, published an article in the January 1966 issue of Management Accounting, which is included as an appendix to this report. He has also lectured to honor students in business administration on the University Park campus and to the Convention of Accounting Professors of the State of Pennsylvania. Professor Cramer presented a lecture to graduate students of Atlanta University entitled "The Computer as a Medium for Teaching of Accounting."

Professor Riedesel, author of the modern mathematics course, made presentations about CAI at the convention of the National Council of Teachers of Mathematics, at the Americana Hotel, New York City, on April 14. His presentation included the use of an overhead projector and a slide projector for displaying 2 x 2-inch slides pertinent to CAI. Other similar CAI presentations made by Professor Riedesel were in Philadelphia to the Association of Educational Data Systems; in April 1967 at the National

Elementary Principals Conference in Boston, Massachusetts, at which time his talk centered around the information gained from experience with CAI and directions in elementary school mathematics; and on May 6, 1967, to the New Jersey Section of the Mathematical Association of America in New Jersey, on CAI in modern mathematics.

Professor Mitzel has made several presentations regarding CAI. He participated in a regional research conference held at University Park campus on November 3, 4, and 5, 1965. This conference was attended by researchers in the field of Agricultural Education from 12 states and from the U. S. Office of Education. Professor Mitzel showed the video-tape recording of a CAI demonstration for this group of people. This same video-tape recording was also used by Professor Mitzel for the Council of Academic Deans at Penn State University on February 28. A set of 2 x 2-inch colored slides have been prepared illustrating the CAI effort at Penn State. These have been used extensively by Professor Mitzel in various presentations he has made. One presentation was to a group of about 20 graduate students at the Institute for Educational Communications at Syracuse University on April 6, 1966. Another presentation was made at Kings College at Wilkes-Barre to the Higher Educational Regional Group on May 10. On June 21, 1967, Professor Mitzel presented a paper to the American Society for Engineering Education at their annual meeting at Michigan State University, in East Lansing, Michigan.

Professor Wodtke has participated in several panel discussions and presentations regarding CAI. In September 1965 he presented a paper on CAI at the American Psychological Association meetings in Chicago, Illinois. He also participated in a panel discussion at the American Educational Research Association meetings in Chicago and during the same period participated in a panel discussion which was organized by the Penn State staff at meetings of the National Society of Colleges of Teacher Education. A paper was presented in early May 1966 at the American Educational Data Systems convention in Philadelphia, Pennsylvania; another at the Pennsylvania Educational Research Association at Bucknell University on May 19, 1967; and one on the educational requirements for a student-subject matter interface, a paper which is included as an appendix to this report, at the Spring Joint Computer Conference held in Atlantic City, New Jersey, on April 19, 1967.

The final dissemination aspect of this project is a 24-minute 16mm sound, color film on computer-assisted instruction produced under the direction of Professor Donald W. Johnson. The title "Sign on/Sign off" is suggestive of one unique requirement of this type of instruction.

The main purpose of the film is to generate an interest in computer-assisted instruction and a desire on the part of the viewers to further explore the potentials of this new medium. The intent, therefore, is to motivate the audience to further explore and study. By so doing, they should become better informed potential users of computers in education.

With the above objective in mind, the film contains short sequences of computers in operation, students at the terminal, teaching-learning situations, remarks of experts, close-ups of displays and type-outs, and other short segments designed to be visually interesting. Scenes are numerous and short to the interest of the viewers.

The film is intended primarily for educators who have had no introduction to computer-assisted instruction. The audience could be in-service teachers or administrators, college students planning to enter the field of education, or interested, informed people outside the field of education. Where possible, the language is non-technical.

After a brief introduction, Sign on/Sign off seeks to establish the need for technology in education by showing school scenes of the early 1900's and contrasting these with current needs; social and technological developments are depicted. The Socratic method with an emphasis on individual differences is related through scenes of a master teacher and five students in a learning situation. The next scene shows learners at the terminal interacting with the same material as in the prior scene; parallels are drawn between teaching as accomplished by a master teacher and that of a computer. Emphasis is again on individualized instruction to meet unique needs of the learners.

The audience is shown how CAI works through an animated sequence utilizing abstract forms to relate certain mechanical and electronic functions. The final scenes are of educators connected with the Penn State project commenting, in their own words, on certain aspects of computer-assisted instruction of interest to the audience.

The 16mm sound film is in color and approximately 24 minutes in length. It was produced by The Pennsylvania State University Motion Picture Production Studio, and when approved by the staff of the U. S. Office of Education, the film will be available through the usual distribution channels.

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APPENDIX A

Page No.

A.1 Summary of Coursewriter Operation Codes . . . 185

Appendix A.1

Summary of Coursewriter Operation Codes

Primary

rd - Computer types text and waits for the student to signal completion. Commonly used to display a reading assignment to a student.

rdn - Same as rd, but does not update restart address.

qu - Computer types text and waits for student to type a response. Commonly used to display questions or problems to a student.

qun - Same as qu, but does not update restart address.

Major

ca - Correct answer to be stored in memory for comparison with student's answer.

cb - Similar to ca - used to identify a set of alternate correct answers - the subsequent action is to be the same regardless of which answer in the set is matched by the student's response.

wa - Wrong answer to be stored for comparison with student's answer.

wb - Similar to wa - used to identify a set of alternate wrong answers - the subsequent action is to be the same regardless of which answer in the set is matched by the student's response.

aa - Anticipated answer - similar to ca and wa, but not followed by implicit branch.

ab - Similar to aa - used to identify a set of alternate anticipated answers - the subsequent action is to be the same regardless of which answer is matched by the student's response.

un - Text to be typed if the student's answer is not one of the specified correct or wrong answers.

nx - Instructs the computer to execute the instruction(s) immediately following the nx. The purpose of the nx is to change a minor operation code (e.g., ty or fn) to a major operation code.

xl - Time limit - computer ignores anything typed by the student after the specified time has lapsed.

Minor

ty - Computer types text and continues without waiting for any response from the student.

br - Branch - alters the sequence of execution
Unconditional: branch is always taken
Conditional: branch is taken only if a particular condition is satisfied.

ad - Adds (algebraically) a number or the contents of a counter to a counter. Commonly used for accumulating a student's errors or response times.

ld - Load - clears a counter and adds a number (or the contents of a counter) into a counter. Load may also be used to set a switch to 0 or 1.

dv - Divide contents of a counter by a constant or by the number in a counter.

mp - Multiply contents of a counter by a constant or by the number in a counter.

fp1 - Display a slide.

fp0 - Seek and position a slide, but does not display it.

tp1 - Play a tape recorded message.

tp0 - Seek and position tape recorded message but does not play it.

tpr - Record a tape recorded message.

fn - Computer executes the specified function. Functions are special series of instructions (written in a machine language subprogram) so that the computer can do processing which cannot be done by using only the Coursewriter operation codes.

fn - slide//n - The display slide function is used to present a slide; n represents the number of the slide to be displayed.

fn - slide//nx - The seek and position slide function will seek and position slide n, but will not show the slide until a display slide function occurs in the program.

fn - tape//n - The play tape function will play tape recording number n.

fn - tape//nx - The seek and position tape function causes tape recording number n to be positioned. The recording will not play until a tape play function occurs in the program.

fn - dc// - The display c-counter function is used to display the contents of a c-counter to the student.

fn - dx// - The display x-counter function is used to display the contents of an x-counter to a student.

fn - wait// - The wait function allows the author to delay the program before execution.

fn - kw// - The key word function allows the author to specify one or more key words which must be matched in the student's answer.

fn - kwo// - The key words ordered function is similar to the key word function. However, the key word ordered function also requires that the matched key words in the student's response are entered in a specified order.

fn - kwi// - The key words initial function searches for the words that have been entered in the ca or wa. If the function finds a word in the student's response not in the ca or wa, the function is terminated.

fn - kw//io - The key words ordered and initial function searches for key words in the student's response. This function insists that the student's response be in a certain order and also checks to insure that there are no unmatched key words in the student's response.

fn - lim - The limits function allows the author to specify mathematical limits within which the student's numerical response will be acceptable.

fn - pa0// - The partial answer zero function allows an author to disregard extraneous discrepancies between a student's response and the text of a ca, wa, or aa. This function is used to process answers which are misspelled or partially correct.

fn - irand// - The pseudo random integer function allows authors to specify that a pseudo random integer be placed in a c-counter.

fn - ic// - The initial characters function allows authors to specify that only a certain designated number of initial characters in the student's response are to be compared with a subsequent ca or wa. The function also allows the author to specify that characters in certain positions of the student's response are irrelevant and are to be considered matched.

fn - ed// - The edit function allows an author to edit the student's response by replacing or deleting characters.

fn - sb// and rb// - The save and branch function (sb) allows the author to insert in one place within a course a certain sequence of material (subroutine) which can be branched to repeatedly thus limiting the necessity for programming the same material at repeated places within the course. The return branch (rb) function returns the student to a point in the course as directed by an address indicated in the text of the sb function.

APPENDIX B

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B.1 Sample of Student's Typeout 191

APPENDIX B.1

SAMPLE OF STUDENT'S TYPEOUT[1]

A Sample of Dialogue between a Student and the Computer for a Section of Instruction on the Anatomy of the Outer Ear

Computer	*Student Responses*
	(EOB)
make a request	
	s1948, spa430
03/31/66 12:18	
L. Dicken spa430	
1-1. Following the normal pathway of sound, type the names of the three main divisions of the ear in their correct order.	
	outer, middle, inner
Good.	
1-2. What is another name for the external ear?	
	external auditory meatus
is one part of the external ear. The desired term includes all of the external ear. Try again.	
	outer
Correct. Another name for the external ear is the outer ear. Be careful of your spelling and typing.	

---

[1] All student responses appear on the right.

Computer	*Student Responses*
1-3. What is the name for that part of the external ear most visible and on the outside of the head?	
	ear
What is the term used in Newby's Figure 2-2 on page 16, for the externally most visible part?	
	pinna
Correct. The terms "pinna" and auricle are synonymous.	
1-4. What small structure of the ear divides the external ear from the middle ear (you need a SPECULUM to see it)?	
	eardrum membrane
is correct. However, a more technical name that we shall be using is: tympanic membrane type: tympanic membrane and press: EOB	
	tympanic membrane

APPENDIX C

Page No.

C.1 Student Attitude Toward Computer Assisted Instruction 195

Appendix C.1

STUDENT ATTITUDE TOWARD COMPUTER ASSISTED INSTRUCTION

This is not a test of information; therefore, there is no one "right" answer to a question. We are interested in your opinion on each of the statements below. Your opinions will be strictly confidential. Do not hesitate to put down exactly how you feel about each item. We are seeking information, not compliments; please be frank.

NAME______________________________________ DATE____________________

NAME OF COURSE ____

CIRCLE THE RESPONSE THAT MOST NEARLY REPRESENTS YOUR REACTION TO EACH OF THE STATEMENTS BELOW:

1. While taking Computer Assisted Instruction I felt challenged to do my best work,

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

2. The material presented to me by Computer Assisted Instruction caused me to feel that no one really cared whether I learned or not.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

3. The method by which I was told whether I had given a right or wrong answer became monotonous.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

4. I was concerned that I might not be understanding the material.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

5. I was not concerned when I missed a question because no one was watching me anyway.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

6. While taking Computer Assisted Instruction I felt isolated and alone.

All the time	Most of the time	Some of the time	Cnly occasionally	Never

7. While taking Computer Assisted Instruction I felt as if someone were engaged in conversation with me.

All the time	Most of the time	Some of the time	Only occasionally	Never

8. The responses to my answers seemed appropriate.

All the time	Most of the time	Some of the time	Only occasionally	Never

9. I felt uncertain as to my performance in the programmed course relative to the performance of others.

All the time	Most of the time	Some of the time	Only occasionally	Never

10. I found myself just trying to get through the material rather than trying to learn.

All the time	Most of the time	Some of the time	Only occasionally	Never

11. I knew whether my answer was correct or not before I was told.

Quite often	Often	Occasionally	Seldom	Very Seldom

12. I guessed at the answers to questions.

Quite often	Often	Occasionally	Seldom	Very Seldom

13. In a situation where I am trying to learn something, it is important to me to know where I stand relative to others.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

14. I was encouraged by the responses given to my answers of questions.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

15. As a result of having studied some material by Computer Assisted Instruction, I am interested in trying to find out more about the subject matter.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

16. In view of the time allowed for learning, I felt too much material was presented.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

17. I was more involved in running the machine than in understanding the material.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

18, I felt I could work at my own pace with Computer Assisted Instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

19. Computer Assisted Instruction makes the learning too mechanical.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

20. I felt as if I had a private tutor while on Computer Assisted Instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

21. I was aware of efforts to suit the material specifically to me.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

22. I found it difficult to concentrate on the course material because of the hardware.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

23. The Computer Assisted Instruction situation made me feel quite tense.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

24. Questions were asked which I felt were not relevant to the material presented.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

25. Computer Assisted Instruction is an inefficient use of the student's time.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

26. I put in answers knowing they were wrong in order to get information from the machine.

:	:	:	:	:
Quite often	Often	Occasionally	Seldom	Very seldom

27. Concerning the course material I took by Computer Assisted Instruction, my feeling toward the material before I came to Computer Assisted Instruction was:

:	:	:	:	:
Very favorable	Favorable	Indifferent	Unfavorable	Very unfavorable

28. Concerning the course material I took by Computer Assisted Instruction, my feeling toward the material after I had been on Computer Assisted Instruction is:

:	:	:	:	:
Very favorable	Favorable	Indifferent	Unfavorable	Very unfavorable

29. I was given answers but still did not understand the questions.

:	:	:	:	:
Quite often	Often	Occasionally	Seldom	Very seldom

30. While on Computer Assisted Instruction I encountered mechanical malfunctions.

:	:	:	:	:
Very often	Often	Occasionally	Seldom	Very seldom

31. Computer Assisted Instruction made it possible for me to learn quickly.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

32. I felt frustrated by the Computer Assisted Instruction situation.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

33. The responses to my answers seemed to take into account the difficulty of the question.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

34. I could have learned more if I hadn't felt pushed.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

35. The Computer Assisted Instruction approach is inflexible.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

36. Even otherwise interesting material would be boring when presented by Computer Assisted Instruction.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

37. In view of the effort I put into it, I was satisfied with what I learned while taking Computer Assisted Instruction.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

8. In view of the amount I learned, I would say Computer Assisted Instruction is superior to traditional instruction.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

9. Whith a course such as I took by Computer Assisted Instruction, I would prefer Computer Assisted Instruction to traditional instruction.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

0. I am not in favor of Computer Assisted Instruction because it is just another step toward de-personalized instruction.

:	:	:	:	:
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree

HIS SPACE IS PROVIDED FOR ANY COMMENTS YOU CARE TO MAKE ABOUT COMPUTER ASSISTED INSTRUCTION.

APPENDIX D

Speech Pathology and Audiology CAI Course

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D.2 Anatomical Slide Description for SPA 430 . . 207

D.3 Sample of Speech Pathology and Audiology CAI Program 213

D.4 Flow Chart and Interpretive Notes for the First Part of SPA 430 223

D.5 Sample Static Display for SPA 430 225

D.6 Sample Student Handout for SPA 430 227

Appendix D.1

Sample of Speech Pathology and Audiology Self-Study Guide

SPA 430

This is the Penn State Course Speech Pathology and Audiology 430: Introduction to Audiology. SPA 430 is taught by individual work and by classroom instruction. There is one classroom period per week. It is the student's responsibility to schedule the required individual work at the study center after each classroom period and before the next class meeting.

The textbook for this course is Audiology (2nd Edition) by Hayes A. Newby. Because the study material often refers to the book, it should be available at all sessions, as well as during the class periods.

Now proceed to the following study materials. They will be given to you in this folder, a week's work at one time.

The plan is to present a question, and then to give its answer or to give you a series of directions. There are a number of audio-visual aids, such as models and slides to help you. Also, you are to have a number of handout sheets to be completed as instructed. Use the study materials to your best advantage, but in general follow the sequence as presented.

The materials are in "chapters," but these are not the same as chapters in your textbook. Each question has an identification number indicating chapter and question number. Occasionally a number will be skipped because it is not needed, (even though the question was given for convenience for students working at the CAI terminal).

You should ask the proctor for the necessary models, handout materials, slides, and slide projector facility. The slides are identified by Aud. numbers.

When you are finished with a study session return all models and slides to the proctor. Keep your folder and handouts for your own use, or leave them with the proctor as you wish.

You are to proceed with these study materials at your own pace and schedule.

However, you must complete all of a week's work during that week. Do not fall behind, because you must be ready for the next week's work.

Materials for Chapter I

Handouts (in your folder):

Right Human Pinna

Aspects of Temporal Bone

Schema Right Ear: Transverse Section

Slides (by number; obtain from proctor)

4, 8-9, 19-20

Other (obtain from proctor):

Pinna

Skull

SPA 430

Chapter I

If you have not done so already, read pages 16-18 in Newby. When this reading is completed, proceed.

Here are the main points you should know:

1. Three main divisions of the ear
2. Names and functions of the parts of the outer ear
3. Names of the parts of the pinna (per your Handout)
4. Correct spelling of the anatomical terms

Now begin the question-answer sequence.

1-1. Following the normal pathway of sound, what are the names of the three main divisions of the ear in their correct order.

outer ear, middle ear, inner ear

1-2. What is another name for the outer ear?

External ear is correct. The first division of the ear is the outer or external ear.

1-3. What is the name for the part of the external ear most visible and on the outside of the head?

auricle or pinna. The terms pinna and auricle are synonymous. . . . .

Appendix D.2

ANATOMICAL SLIDE DESCRIPTION FOR SPA430

Week No.	Chapter No.	Slide No.	Title of Slide and Brief Description
1	1	4	*THE RIGHT HUMAN PINNA (Similar to student's Handout with no parts labeled)
1	1	8	THE RIGHT HUMAN PINNA (This has seven of the parts labeled)
1	1	9	*THE RIGHT HUMAN PINNA (Similar to student's Handout with all parts labeled)
1	1	19	*ASPECTS OF TEMPORAL BONE (Similar to student's Handout with all parts labeled)
1	1	20	*SCHEMA RIGHT EAR--TRANSVERSE SECTION (Similar to student's Handout with all parts labeled)
1	2	28	RIGHT TYMPANIC MEMBRANE (This slide is used to quiz students on the CAI terminal to see whether or not they know four parts of the tympanic membrane.)
1	2	29	RIGHT TYMPANIC MEMBRANE (Part of the student's Handout is filled in and labeled.)
1	2	30	*RIGHT TYMPANIC MEMBRANE (Similar to student's Handout with all parts filled in.)
1	2	31	*LEFT TYMPANIC MEMBRANE (Filled in and complete labeled student's Handout.)
2	3	32	SCHEMA: MIDDLE EAR (Part of student's Handout filled in, no labels.)
			SCHEMA: MIDDLE EAR (More of student's Handout filled in, again, no labels.)

Week No.	Chapter No.	Slide No.	Title of Slide and Brief Description
2	3	34	SCHEMA: MIDDLE EAR (Part of student's Handout filled in and labeled.)
2	3	35	SCHEMA: MIDDLE EAR (Similar to slide 34 with the sole exception that the stirrup has been added to the oval window and is highlighted.)
2	3	36	SCHEMA: MIDDLE EAR (Partially completed student Handout and labeled.)
2	3	37	*SCHEMA: MIDDLE EAR (Completed student Handout, all parts labeled.)
2	4	40	*HAMMER (All parts of the hammer are labeled.)
2	4	41	*ANVIL (All parts of the anvil are labeled.)
2	4	42	*STIRRUP (All parts of the stirrup are labeled.)
2	4	44	*OSSICULAR ARTICULATION (Various ligaments, membranes are shown in red.)
2	4	45	*OSSICULAR ARTICULATION (The inward phase of sound is shown with orange arrows throughout.)
2	4	46	*OSSICULAR ARTICULATION (The outward phase of sound is shown with green arrows throughout.)
2	5	60	*EUSTACHIAN TUBE SECTION (Similar to student's Handout with all parts labeled.)
2	5	68	*PHARYNX AND ADJACENT STRUCTURES (Similar to student's Handout with all parts labeled.)
2	5	77	*SCHEMATIC OF MOUTH (Similar to student's Handout with all parts labeled.)

Week No.	Chapter No.	Slide No.	Title of Slide and Brief Description
2	6	9a*	*LATERAL VIEW OF SUPERFICIAL MUSCLES OF FACE AND NECK (Masseter and sternocleidomastoid muscles shown)
2	6	11a	*LATERAL VIEW OF PHARYNGEAL CONSTRICTORS (Shows pharyngeal constrictors.)
2	6	33a	*ORAL CAVITY (This is taken from Netter plate #1.)
2	6	34a	*PHARYNX (SAGGITAL SECTION) (This is Netter's plate 16.)
2	6	35a	*MUSCULATURE OF PHARYNX (This is Netter's plate #20.)
2	6	36a	*PHARYNX (VIEWED FROM BEHIND) (This is Netter's plate #17.)
2	6	37a	*MUSCULATURE OF PHARYNX (VIEWED FROM BEHIND) (Netter's plate #21.)
2	6	38a	*MUSCULATURE OF PHARYNX (SAGGITAL SECTION) (Netter's plate #19.)
2	6	39a	*ROOF OF MOUTH (VIEWED FROM BEHIND) (Netter's plate #5.)
2	6	40a	*FAUCES (SAGGITAL SECTION) (Netter's plate #14.)
2	6	41a	*LEAVTOR AND TENSOR MUSCLE SCHEMA (Dr. Siegenthaler's drawing of these muscles.)
2	6	42a	*EUSTACHIAN TUBE OPENING I (Velum lowered)
2	6	43a	*EUSTACHIAN TUBE OPENING II (Velum raised. Passavant's bar is shown.)
2	6	44a	*EUSTACHIAN TUBE OPENING III (Velum intermediate)

*The "a" designates the second tray of slides in the CAI group.

Week No.	Chapter No.	Slide No.	Title of Slide and Brief Description
3	7	10a	*SCHEMATIC OF OSSEOUS LABYRINTH (Similar to student's Handout with all parts labeled.)
3	7	12a	COCHLEAR CANAL I (Long closed tube.)
3	7	13a	COCHLEAR CANAL II (Same as slide 12a with spiral lamina added.)
3	7	14a	COCHLEAR CANAL III (Same as 13a with tube curved.)
3	7	15a	COCHLEAR CANAL IV (Same as slide 14a with tube helical.)
3	7	16a	*COCHLEAR CANAL V (Slide as 15a with cone (modiolus) inserted inside helix.)
3	7	18a	*MODIOLUS WITH FORAMINA (Similar to slide 17a with cutout showing foramina in modiolus.)
3	7	19a	*SECTIONAL VIEW OF COCHLEA (Cross section of cochlea.)
3	8	20a	MEMBRANOUS LABYRINTH I (Similar to student's Handout with 11 osseous parts to be labeled listed on bottom.)
3	8	21a	MEMBRANOUS LABYRINTH II (The parts given on slide 20a are now labeled.)
3	8	22a	MEMBRANOUS LABYRINTH III (Shows membranous vestibule with parts not labeled.)
3	8	23a	MEMBRANOUS LABYRINTH IV (Same as slide 22a with parts labeled.)
3	8	24a	MEMBRANOUS LABYRINTH V (Membranous semi-circular canal added with parts not labeled.)
3	8	25a	MEMBRANOUS LABYRINTH VI (Same as slide 24a with parts labeled.)

Week No.	Chapter No.	Slide No.	Title of Slide and Brief Description
3	8	26a	MEMBRANOUS LABYRINTH VII (Cochlear duct added with parts listed but not labeled.)
3	8	27a	MEMBRANOUS LABYRINTH VIII (Similar to slide 26a with parts labeled.)
3	8	28a	MEMBRANOUS LABYRINTH IX (Spiral lamina added.)
3	8	29a	*MEMBRANOUS LABYRINTH X (Similar to student's completed Handout with all parts added and labeled.)
3	8	30a	MEMBRANOUS LABYRINTH XI (CONNECTIONS TO BRAIN) (Similar to student's second Handout showing osseous connections to brain cavity, no parts labeled but parts are listed.)
3	8	31a	*MEMBRANOUS LABYRINTH XII (CONNECTIONS TO BRAIN) (Similar to slide 30a with all parts labeled.)
3	9	50a	WHICH WAY IS DOWN? (Man's head with maculae shown in utricle and saccula.)
3	10	51a	*SCHEMA OF COCHLEAR CANAL (Similar to student's Handout with all parts labeled.)
3	10	52a	*ORGAN OF CORTI (Similar to student's Handout with all parts labeled.)
4	11	53a	*SCHEMA OF COCHLEAR NEURON CONNECTIONS (Three pathways of VIII N. neurons are shown in cochlear canal.)
4	11	54a	*MAJOR TOPOGRAPHY OF BRAIN (Five lobes of brain with other prominent features shown. Lateral view.)

Week No.	Chapter No.	Slide No.	Title of Slide and Brief Description
4	11	55a	*SEVERAL SPECIALIZED BRAIN AREAS (Broca's area, Heschel's area and Wernike's area are shown.)
4	11	56a	*ACOUSTIC SYSTEM I (Similar to student's Handout and no parts labeled.)
4	11	57a	*ACOUSTIC SYSTEM II (First order neurons shown.)
4	11	58a	*ACOUSTIC SYSTEM III (Second order neurons shown.)
4	11	59a	*ACOUSTIC SYSTEM IV (Higher order neurons shown.)
4	12		NO ANATOMICAL SLIDES
4	13		NO ANATOMICAL SLIDES

Appendix D.3

Sample of Speech Pathology and Audiology CAI Program

```
Label    Op Code    Argument

                          This section is taken from the
                        fourth chapter of spa430; Chapter 4
                        covers the contents and functions of
                        the middle ear.  The sample program
                        below demonstrates one of the ways a
                        student is guided by a series of
                        questions to complete an anatomical
                        Handout.  It tells the student to fill
                        in his Handout unaided - then shows
                        the student a slide of a completed
                        Handout - and finally asks the student
                        to question the computer on the items
                        missed.  This procedure is intended
                        to allow a student to proceed at the
                        pace he requires, while presenting
                        all of the material to all of the
                        students.*

           rd
           fn       tape//85x
           fn       slide//43x
           ty       ,,(linefeed),,

                          This generates extra spacing
                        between typeouts.  This format helps
                        separate items within the program.

           ty       4-1.  We have just completed a schematic
                    representation of the boundaries of the
                    middle ear cavity.  The problem for hearing
                    is to get "sound" across the region of the
                    middle ear cavity from the eardrum to the
                    oval window.  So far this linkage is not
                    complete.  Now we shall complete it by
                    means of the ossicular chain.
```

---

*N. B. All material indented to this position represents author's explanatory comments about the stored computer program.

```
Label     Op Code    Argument

            ty        ,,(linefeed),,
            qu        Have you read pp. 18-21 in Newby?
            nx
            fn        kw//l
            ca        / yes
                            An example of keyword processing;
                        the slash (/) is used as a delimiter
                        to separate keyword responces.  The
                        computer searches the student's re-
                        sponse for a grouping of letters
                        "yes."  If "yes" is anywhere in the
                        response, the following ty is typed
                        out.
            ty        Now pay special attention to p. 19.  Fig. 2-4.
                      Take the three plastic ossicles; look at
                      them carefully and compare them with Fig.
                      2-4.  The lenticular process of the incus
                      is distorted in the sketch.  However, for
                      our purposes, both the sketch and the
                      plastic ossicles are from a right ear.
                      Study the names of the various parts of
                      each ossicle until you think you know them
                      fairly well.  Then close your book and
                      press:  EOB

            nx
            fn        kw//l
            wa        / no
            ty        Do it now.  Type yes when you are through
                      reading.
            fn        wait//30
                            This prevents the student from
                        proceeding for 30 seconds; presumably
                        sufficient time to "stimulate" the
                        student into doing the required reading
                        assignment.

            un        Type either:  yes  (or)  no
            rd        ,,,,
```

Label	Op Code	Argument
	ty	,,(linefeed),,
	ty	The next Handout is intended to show the ossicles of the right ear in their approximate relation to each other but disarticulated. Along with your Handout, have on hand the three plastic ossicles and Newby. Press: EOB when you are ready to begin.

The student is referred to his Handout, which contains a sketch of each of the three bones in the middle ear (ossicles). On the Handout, lettered extension lines point to each of the parts of interest. Below each ossicle is a list of parts. It is the student's responsibility to match the part with the line.

Label	Op Code	Argument
	rd	,,,,
	ty	,,(linefeed),,
	ty	4-2. Consider the hammer. Using words found in the list below the sketch of the hammer, fill in those lines (A-H) that you are very sure you know. You may leave some lines blank for now. For your own benefit, don't do this by the process of elimination. Press: EOB when this is completed.
	fn	wait//15
4-2	rd	,,,,
	ty	,,(linefeed),,
	fn	slide//43

Slide 43

1. If you cannot identify all the labeled parts of this ossicle, type the letter of one unlabeled part. Material will then be presented to help you fill in the unlabeled part.

```
Label     Op Code     Argument

                      Slide 43 (cont'd)

                      2.  Repeat Step #1 as often as desired.
                      3.  When all parts of this ossicle are
                          labeled, type:  go on
                      ______________________________________

          qu          ,,,,
          ca          go on

                          When the student has labeled all
                          the parts of the ossicle, he types:
                          go on  (see slide 43).  Upon typing
                          go on  the following ty is typed out
                          and slide 40 is shown, followed by
                          tape message 85.

          ty          Compare your Handout with the following slide.
          fn          slide//40
                      ______________________________________

                      Slide 40

                      This slide shows a sketch of the ossicle the
                      student has just completed, completely
                      labeled.
                      ______________________________________

          fn          tape//85
                      ______________________________________

                      Tape Message 85

                      Check your Handout with the slide.  Notice
                      that the names of the parts of the hammer
                      make sense.  For example, the head of the
                      hammer is attached to the neck.  The liga-
                      ments and processes are names for the
                      direction toward which they point.
                      ______________________________________

          ty          ,,(linefeed),,
          fn          tape//86x
```

```
Label    Op Code    Argument

         nx
         fn         sb///nxl//a0///alpha
```

If the student has not typed "go on" he will be asking for information about one of the parts of the ossicle (see contents of slide 43). This statement is a subroutine used to make sure that the student's response consists of one letter only. The student's response cannot be further processed until this criterion has been met.

```
         nx
         fn         kw//1
         ca         /a
         fn         slide//43x
         ty         ,,(linefeed),,
         br         hmr-a
```

The above set of six statements processes the one letter response of the student to see if the letter "a" is typed. The combination of the subroutine (previously described) and the keyword processing in this set makes it possible for a student to type any variation of the letter "a" and still be recognized. (a a. A A. -a) are examples of what would be recognized as correct

```
         nx
         fn         kw//1
         ca         /b
         fn         slide//43x
         ty         ,,(linefeed),,
         br         hmr-b
```

Label Op Code Argument

Since the first ossicle, the hammer, has eight parts, the processing of student responses *a* through *h* takes place in the same way.

```
        nx
        fn      kw//l
        ca      /h
        fn      slide//43x
        ty      ,,(linefeed),,
        br      hmr-h
        nx
        fn      kw//l
        wa      /i/j/k/l/m/n/o/p/q/r/s/t/u/v/w/x/y/z
```

The purpose of this keyword processing is to insure that the student typed a letter that is in the repetoire of responses. Here, the letters *i* through *z* have no meaning as a response.

```
        ty      You should have typed a letter referring to
                the hammer.  You didn't.  Try again.

        un      Read the slide.  Type:  go on  if all parts
                of the hammer are labeled.  If not all
                labeled, type the letter of one unlabeled
                part.

        qu      If you have made an error or two and would
                like some help, type:  help
                If your labels are all correct and you are
                ready to proceed with the anvil, type:  anvil
```

This *qu* can only be reached by the student who has completed the first ossicle and is ready to proceed to the second one. At this point, the student is given another opportunity to go over the parts of the first ossicle (by typing HELP). The student also may proceed to the second ossicle, the anvil, by typing ANVIL.

```
Label     Op Code    Argument

          nx
          fn         pa0//2//50
          ca         help
          br         4-2
          nx
          fn         pa0//2//60
          ca         anvil
          fn         slide//43x
          ty         ,,(linefeed),,
          br         4-3
          un         Type either:  help  (or)  anvil

                         Here we start the processing of
                     the eight (a-h) information seeking
                     responses the student can make.  After
                     the student has been through the
                     series of statements that contain
                     information on the part desired, the
                     computer goes back to showing slide
                     43 and processing the student's
                     response again--as often as desired.

hmr-a     qu         Part A is the topmost part of the malleus.
                     Note that it is the part of the hammer that
                     "strikes" the anvil.  What part of a hammer
                     strikes an anvil?

          nx
          fn         kw//1
          ca         /head
          ty         Correct.  Label A as head
          fn         wait//5
          br         4-2
          un         A is the topmost part of the malleus.  What
                     is your topmost part?
```

```
Label      Op Code    Argument
```

The un response is typed out to the student whenever he responds with something unanticipated by the author.

```
           un         Incorrect.  Try again.
           un         Try:  head
                      Type it.
```

Here is similar processing for student response: b

```
hmr-b      qu         Part B represents a ligament.  Which one?
           nx
           fn         kw//1
           ca         / lateral
           ty         Correct.
           fn         tape//86
           fn         tape//87x
           fn         wait//5
           br         4-2
           wa         sideward
```

The wa is an example of a possible anticipated wrong response. If "sideward" is typed by the student, the following ty is typed out.

```
           ty         Correct.  However, answer the question again
                      using the more technical anatomical term
                      for things going to the side.
           nx
           fn         kw//1
           wa         / up/ for
```

This wa is processed with keyword. Therefore, all student responses starting with the letters "up" or "for" (e.g., up, upward, forward) will have the following ty typed out.

```
           ty         Incorrect.  Look at B and at the word list.
                      Try again.
```

Label	Op Code	Argument
	un	There are only three ligaments on the list of terms below the hammer. Does B point forward, sideward, or upward? Try again.
	un	What term(s) on the list refer to a ligament pointing to the side? Try again.
	un	Type: lateral ligament

Similar processing occurs for student responses c through g.

hmr-h	qu	Part H is an area specialized for contact with a second bone (notice the dotted line). What does H refer to?
	nx	
	fn	kwo//2

The correct answer to the above question must contain at least two words in the correct order. The function kwo (keyword order) matches a student's response when it contains the words "facet" and "incus" in that order no matter what else is typed before, between, or afterwards.

	ca	/ facet / incus
	ty	Correct.
	fn	tape//89
	fn	tape//90x
	fn	wait//5
	br	4-2
	un	The special name for this area is "facet." Try again.

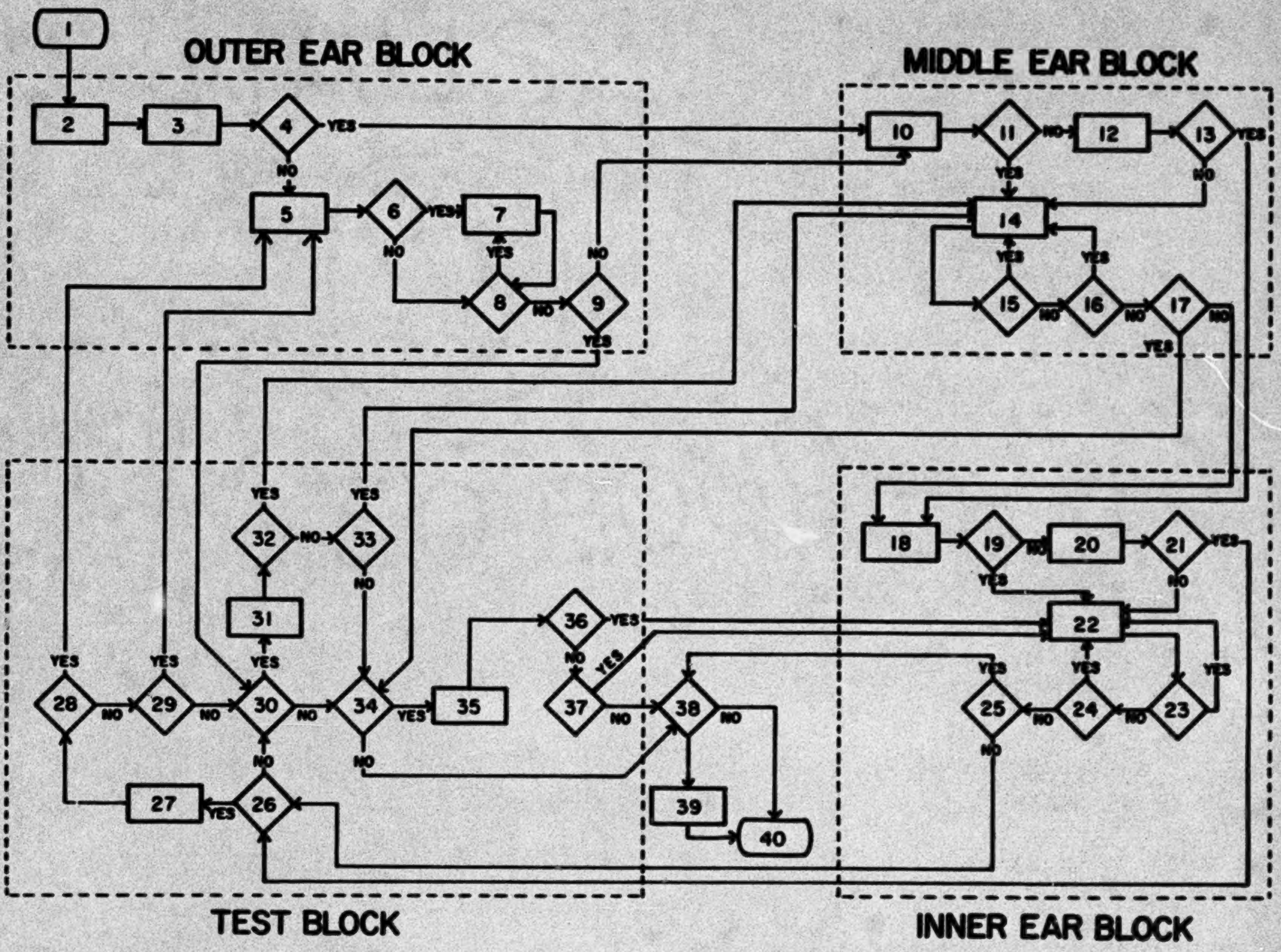
This is the beginning of a similar presentation on the second ossicle.

4-3	rd	

Label	**Op Code**	**Argument**
	ty	4-3. Now consider the anvil. Following the same procedure that you used with the hammer, fill in only those lines (I-M) that you are very sure about. You may leave some lines blank for now. For your own benefit, don't do this by the process of elimination. When you are ready to proceed, press: EOB.

Appendix D.4

Flow Chart and Interpretive Notes for the First Part of SPA 430



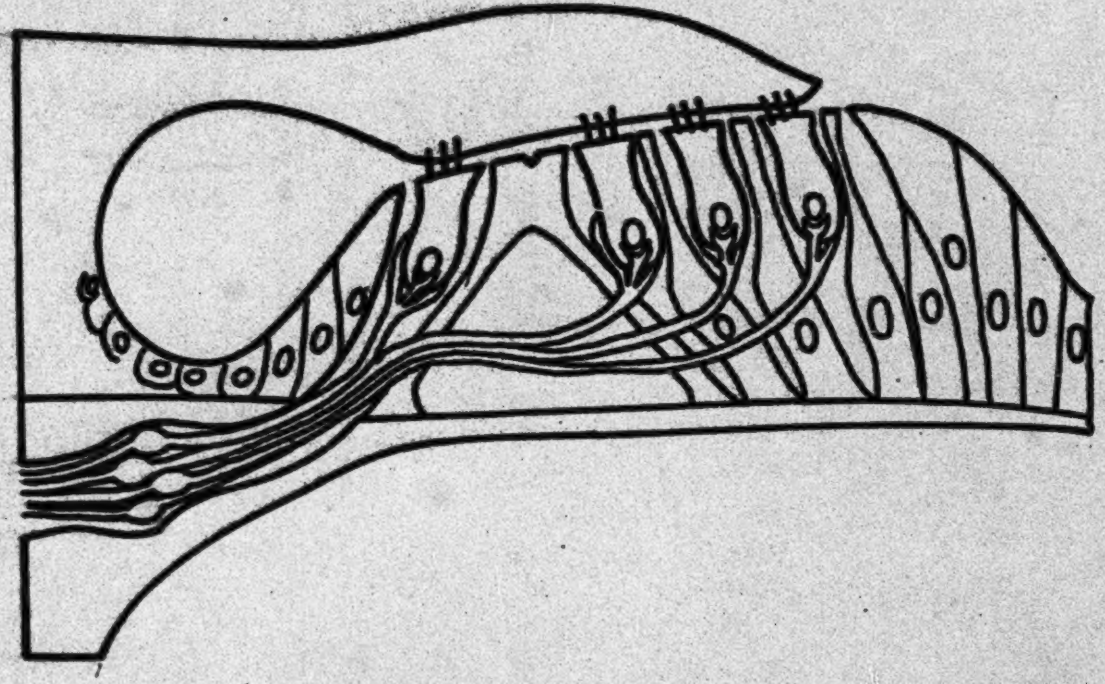
KEY TO FLOW CHART

1. Sign on . Type :-start Press : EOB
2. Introduction to CAI SPA 430
3. Overview of outer ear
4. "Do you want to skip outer ear?"
5. Outer ear subprogram
6. Did student make ⩾ 33% errors on pinna?
7. Remedial subprogram on pinna
8. "Do you want to cover pinna again?"
9. Did student come from Test Block (Outer Ear)?
10. First question on middle ear
11. Did student make ⩾ 33% errors on pinna?
12. Overview of middle ear
13. "Do you want to skip middle ear?"
14. Middle ear subprogram
15. Did student make ⩾ 50% errors on middle ear?
16. "Do you want to cover middle ear again?"
17. Did student come from Test Block (middle ear)?
18. First question on inner ear
19. Did student make ⩾ 25% errors on the last time through middle ear subprogram?
20. Overview of inner ear and temporal bone
21. "Do you want to skip inner ear and temporal bone?"
22. Inner ear and temporal bone subprogram
23. Did student make ⩾ 50% errors on inner ear and temporal bone?
24. "Do you want to cover inner ear and temporal bone again?"
25. Did student come from Test Block (inner ear and temporal bone)?
26. Did student skip outer ear subprogram?
27. Test on outer ear
28. Did student make ⩾ 33% errors on outer ear test?
29. "Do you want to take outer ear subprogram?"
30. Did student skip middle ear subprogram?
31. Test on middle ear
32. Did student make ⩾ 33% errors on middle ear test?
33. "Do you want to take middle ear subprogram?"
34. Did student skip inner ear and temporal bone subprogram?
35. Test on inner ear and temporal bone
36. Did student make ⩾ 33% errors on inner ear and temporal bone test?
37. "Do you want to take inner ear and temporal bone subprogram?"
38. "Do you want to ask any questions?"
39. "Type your questions"
40. On with the course. Proceed to chapter 2: Detailed Anatomy of Ear

Appendix D.5
Sample Static Display for SPA 430

ORGAN OF CORTI

C·A·I Spa 430
3/66



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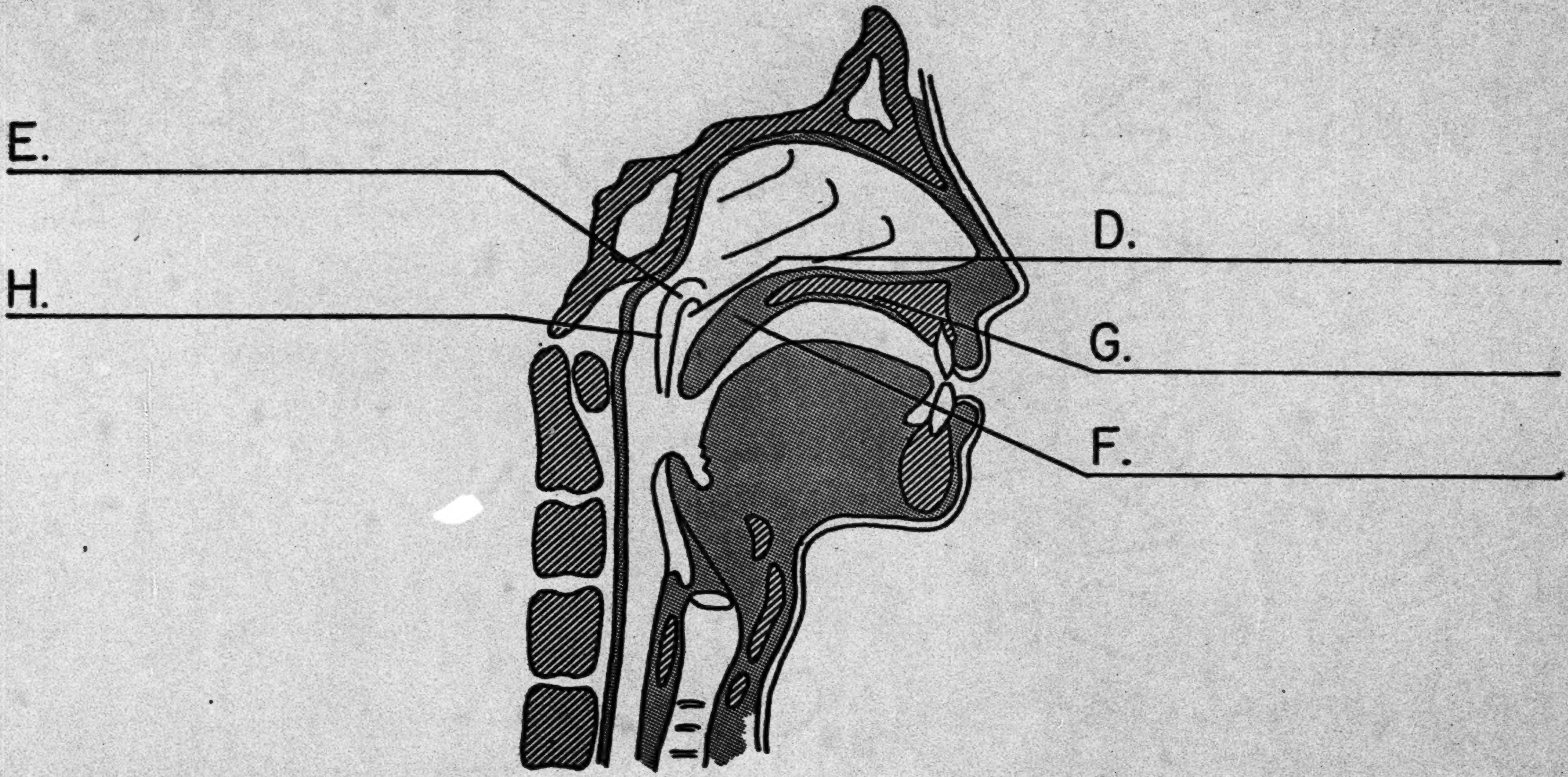
Appendix D.6
Sample Student Handout for SPA 430

PHARYNX & ADJACENT STRUCTURES

C·A·I Spa 430
12/65



orifice of Eustachian tube
torus tuberus
hard palate
fossa of Rossenmuller
soft palate
nasopharynx

APPENDIX E

Introductory Management Accounting CAI Course

Page No.

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Appendix E.1

SUPPLEMENTARY READING ASSIGNMENT
(To accompany Chapter 9 of Keller-Ferrara Text)

As indicated in the "Instructions for Chapter 9," you were not required to read the section entitled "Basic Entries in Standard Cost Systems." The first section of the supplementary reading assignment is intended as a replacement for the above section of Chapter 9. The second section consists of a brief discussion of the spoilage variance.

Journal Entries Under Standard Cost Systems

The method of recording standard costs in the accounts, as set forth below, is generally referred to as the single plan.[1] Under the single plan, work in process is charged (debited) with standard cost of operations (expressed in terms of equivalent units) completed, and work in process is credited with standard cost of finished goods completed. Separate accounts are maintained for each of the variances.[2] Standard cost journal entries as illustrated below are based on data previously presented in the section of Chapter 9 titled "Calculating Variances--A Complete Illustration."

---

[1] Terminology same as that appearing in Accountants Cost Handbook, 2nd Edition, Robert J. Dickey, Editor (The Ronald Press Company, New York, 1960), Section 16.

[2] And be careful to note that the "best" method of calculating variances is employed at this point. More specifically, only one variance is used for variable factory overhead (i.e., the variable overhead efficiency variance) and two for fixed factory overhead.

The problem involves a manufacturer of "gadgets" who has the following standard cost for each 10,000 units produced:

Materials: 10,000 pounds @ $0.0005 per pound	$50.00
Labor: 40 hours @ $2.00 per hour	80.00
Variable factory overhead @ $0.30 per standard direct labor hour	12.00
Fixed factory overhead @ $0.20 per standard direct labor hour	8.00
TOTAL STANDARD COST	$150.00

During the year 50,000 units were manufactured; normal volume was calculated as 220 direct labor hours. The following data appear in the records:

(1) Purchased 60,000 pounds of materials at $0.004 per pound.
(2) Used 52,000 pounds of materials (actually costing $0.004 per pound).
(3) Actual direct labor hours worked amount to 190 at a rate of $2.10 per hour.
(4) Actual variable factory overhead amounted to $76.00.
(5) Actual fixed factory overhead amounted to $45.00.

A complete set of journal entries to reflect the above data in the accounts is presented below. While work in process is both charged and credited at standard cost, the variance accounts serve as a reconciliation of "actual" and standard costs (since by closing the variance accounts into work in process prior to transfers, the account will be converted to "actual" costs). Variance calculations have been omitted since they are identical to those appearing in the section titled "Calculating Variances--A Complete Illustration."

(1)
To record purchase of raw materials*

Dr. Raw materials inventory (@ std. cost). .$300.00
Cr. Materials price variance . . . .$ 60.00
Cr. Accounts payable 240.00

To charge raw materials inventory account for actual quantities of materials purchased at standard cost, to credit accounts payable for actual amount due creditors, and to debit or credit materials price variance account for the difference.

(Notice that the variance accounts may be debited or credited depending on facts given in the problem.)

* Under the single plan, raw materials inventory is carried in the accounts at standard cost. In view of the responsibility accounting concept it is preferable to record the materials price variance on the basis of actual purchases so that the time lag between purchase and usage does not obviate the control significance of this variance! Regretfully, in some problem situations data with respect to purchases are not given in which case the materials price variance must be calculated on the basis of amounts requisitioned. In the above example, the alternative takes the following form:

Dr. Work in process (@ std. cost). $250.00
Dr. Materials usage variance 10.00
Cr. Materials price variance . . . .$ 52.00
Cr. Raw materials inventory (@ actual cost). . . 208.00

(Obviously, raw materials inventory is carried in the accounts at actual cost if recording of the materials price variance is deferred until the date of requisition or usage. Note also that the materials usage variance is also included in the above entry.)

(2)
To record raw materials requisitioned

Dr. Work in process (@ std. cost). $250.00
Dr. Materials usage variance 10.00
Cr. Raw materials inventory (@ std. cost). $260.00

To charge work in process for standard quantities of materials allowed for production meeting standard requirements, to credit raw materials inventory for actual quantities used at standard cost, and to debit or credit materials usage variance for the difference.

(3)

To record direct labor

Dr. Work in process (@ std. cost). $400.00
Dr. Labor rate variance. 19.00
Cr. Labor efficiency variance. . . . .$ 20.00
Cr. Accrued payroll. 399.00

To charge work in process for standard quantities of direct labor allowed for production meeting standard requirements, to credit accrued payroll for actual (gross) amount due workers, and to debit and/or credit labor rate and efficiency variance accounts for the difference.

(4a)

To record actual variable factory overhead incurred

Dr. Variable factory overhead (control account). $76.00
Cr. Appropriate asset, valuation or contra and liability accounts. $76.00

(4b)

To record actual fixed factory overhead incurred

Dr. Fixed factory overhead (control account) $45.00
Cr. Appropriate asset, valuation or contra and liability accounts. $45.00

(5a)

To record variable factory overhead applied to production

Dr. Work in process (@ std. cost). $60.00
Cr. Applied variable factory overhead. $60.00

To charge work in process for standard quantities of variable factory overhead allowed for production meeting standard requirements and to credit applied variable factory overhead control account for same amount.

(5b)

To record fixed factory overhead applied to production

Dr. Work in process (@ std. cost). $40.00
Cr.   Applied fixed factory overhead $40.00

To charge work in process for standard quantities of fixed factory overhead allowed for production meeting standard requirements and to credit applied fixed factory overhead control account for same amount.

(6a)

To reflect variable factory overhead efficiency variance in the accounts

Dr. Applied variable factory overhead. . . .$60.00
Dr. Variable factory overhead efficiency variance 16.00
Cr.   Variable factory overhead (control account) $76.00

To close "actual" and "applied" variable factory overhead accounts and debit or credit variable factory overhead efficiency variance for the difference. (Notice that the difference between the two variable overhead accounts always represents the variance under this method of recording the entries.)

(6b)

To reflect fixed factory overhead variances in the accounts

Dr. Applied fixed factory overhead $40.00
Dr. Fixed factory overhead volume variance 4.00
Dr. Fixed factory overhead budget variance 1.00
Cr.   Fixed factory overhead (control account) $45.00

To close "actual" and "applied" fixed factory overhead accounts and debit and/or credit the difference to the appropriate variance accounts. (Notice that a closing of these accounts yields a "net" variance. Thus, formulas for the fixed factory overhead budget and volume variances must be used in order to calculate the gross amount of each variance.)

(7)

To record transfer of units completed to finished goods inventory

Dr. Finished goods inventory (@ std. cost) . . .$750.00
Cr. Work in process (@ std. cost). $750.00

To record completion of 50,000 units at a standard cost of $150.00 per 10,000 units.

When the gadgets are sold, finished goods inventory should be credited and cost of goods sold debited for the standard cost of units sold.

NOTE: A FIRST STEP IN RECORDING ENTIRES UNDER A STANDARD COST SYSTEM TAKES THE FORM OF DETERMINING STANDARD PRODUCTION WITH RESPECT TO EACH OF THE COST ELEMENTS. GENERALLY, ONE FIGURE IS GIVEN IN PROBLEM SITUATIONS WHICH INDICATES THE NUMBER OF STANDARD UNITS OF OUTPUT PRODUCED DURING THE ACCOUNTING PERIOD!

The Spoilage Variance

This section (of the "Supplementary Reading Assignment" for Chapter 9) should be read after you have studied the section of the chapter which is titled "Additional Variances--The Spoilage Variance." An important conclusion to be drawn from that section is this: Accounting for spoilage under a standard cost system achieves the same results as similar procedures under an "actual" or historical cost system. That is, spoilage must be classified as being either normal (or expected) or abnormal (or unexpected). Costs associated with normal spoilage are reallocated to good units produced, whereas, costs associated with abnormal spoilage are treated as a loss in the income statement for the period.

A special spoilage variance account may or may not be included in the accounts for a standard cost system. Consider the following example where it is first assumed that no spoilage variance account is maintained and second that a special spoilage variance account is maintained:

Standard Cost of Producing One Hat:

Materials: 2 yards of straw @ $0.50 per yard. . .	$1.00
Labor: 1 hour @ $1.50 per hour.	1.50
Variable factory overhead @ $0.50 per standard direct labor hour.	0.50
Fixed factory overhead @ $1.00 per standard direct labor hour	1.00
STANDARD COST OF PRODUCTION BEFORE SPOILAGE.	$4.00
Add on normal (standard) spoilage allowance of 10%.	0.40
STANDARD COST OF PRODUCTION INCLUDING ALLOWANCE FOR NORMAL (STANDARD) SPOILAGE . .	$4.40

The following data appear in the records:

(1) 120 hats were manufactured: 100 meeting standard requirements and 20 unacceptable.

(2) Used 250 yards of straw @ $0.53 per yard.

(3) Actual direct labor hours worked amounted to 125 @ a rate of $1.60.

REQUIRED: Calculate all variances for which data are available.

(1)
Calculations Assuming No Special Spoilage Variance

A review of the above data indicates that the following variances can be calculated:

(1) Materials price variance
(2) Materials usage variance
(3) Labor rate variance
and (4) Labor efficiency variance

When a special spoilage variance is not used, it is necessary to work with the number of standard units produced--in this case 100 hats. Notice that the standard cost of production after adding the 10% allowance for normal spoilage amounts to $4.40. This means simply that the physical standard has been increased by 10% (and consequently the standard cost).

Calculations assuming that no special variance is used for spoilage

(1) Materials price variance -- (SP-AP)AQ

($0.50 - $.053) 250 yards = $7.50 (U)(*)

(2) Materials usage variance -- (SQ-AQ)SP

[2.2 (100) - 250]$0.50
=(220 - 250)$0.50
=$15.00(U)

(3) Labor rate variance -- (SP-AP)AQ

($1.50 - $1.60) 125 hours = $12.50 (U)

(4) Labor efficiency variance -- (SQ-AQ)SP

[1.1(100)-125]$1.50
= (110 - 125)$1.50
= $22.50(U)

Calculations assuming that a special spoilage variance is used

(1) Materials price variance -- Same as above; why?

(2) Materials usage variance -- (SQ-AW)SP

[2(120) - 250]$0.50
= (240 - 250)$0.50
= $5.00 (U)

(3) Labor rate variance -- Same as above; why?

(4) Labor efficiency variance -- (SQ-AQ)SP

(120 - 125) $1.50 = $7.50 (U)

(*) Denote an unfavorable variance by (U) and a favorable variance by (F).

(5) Spoilage variance -- (Actual spoilage - standard spoilage) Standard Cost Before Spoilage

(20-10) $4.00 - $40.00

HOMEWORK ASSIGNMENT:

(1) How is abnormal spoilage treated in a system where a special spoilage variance is not used?

(2) Explain the differences in the usage and efficiency variances under each method.

(3) Why is Standard Cost Before Spoilage used in the formula for the spoilage variance?

(4) Record all entries (for which data are available) under both methods. Remember that units completed are transferred to finished goods at a Standard Cost which includes a spoilage allowance. Why?

Appendix E.2

Case Problems

STANDARD COSTS--ACCOUNTING PROCEDURES
(Instructions for Chapter 9)

In addition to reading introductory material included in Chapter 9, study the following sections very carefully. Omit all sections which are not listed below.

(1) The Variances of Standard Cost Accounting

  (a) Direct Materials Variances
  (b) Direct Labor Variances
  (c) Variable Factory Overhead Variances(*)
  (d) Fixed Factory Overhead Variances--The Budget Variance
  (e) Fixed Factory Overhead Variances--The Volume Variance(*)

(*)In addition to learning formulas and how to calculate all of the variances it is necessary to know the BEST variances for both variable and fixed factory overhead costs. Notice that the sum of the two variances which are "discarded" in each instance yield the BEST variance, i.e., the variable overhead efficiency variance and the volume variance for fixed factory overhead.

(2) Calculating Variances--A Complete Illustration
(Also study Exhibits 9-1 and 9-4)

(3) Calculating Transfers and Ending Inventories

(4) Standard Costs for Individual Areas of Responsibility

(5) Job-Order Standard Costs

  (a) Procedure for Building Standard Costs
  (b) An Illustration: (In order to minimize confusion, it may prove beneficial for you to reread Section 5(b) and rework the example by utilizing journal entries and other procedures as discussed in the SUPPLEMENTARY READING ASSIGNMENT for Chapter 9.) In other words, consider carefully the last paragraph in Section 5(b), which points out the method of recording journal entries as set forth in the above-mentioned "Supplementary Reading Assignment."

(6) Special Issues in Standard Costing

- (a) Additional Variances--The Spoilage Variance (See also the SUPPLEMENTARY READING ASSIGNMENT for Chapter 9.)
- (b) Disposition of Variances (Relate this section to questions in Chapter 8 concerning accounting treatment of "over- or underapplied" fixed factory overhead under each available measure of capacity.)

(7) Appendix A--Alternative Approaches to Fixed Factory Overhead Variances

STANDARD COST VARIANCE ANALYSIS

A fundamental conclusion of Chapter 9 (Keller-Ferrara text) is that seven calculations are necessary to accomplish an elementary level of standard cost variance analysis. Consequently, the following formulas are to be used for problem solution in this course.

MATERIALS

(a) Price variance. . . . .(SP - AP)AQ
(b) Usage or Quantity variance. . . . .(SQ - AQ)SP

LABOR

(a) Rate or Efficiency variance . . . .(SP - AP)AQ
(b) Efficiency or Quantity. . . . .(SQ - AQ)SP

VARIABLE FACTORY OVERHEAD EFFICIENCY VARIANCE[1]

(a) Actual variable factory overhead - Standard direct labor hours* X Standard variable factory overhead rate

[1] Note that this formula is the algebraic sum of the two variable factory overhead variances which are explained in paragraphs two and three of page 204. The explanation which supports use of the above formula is given on pp. 204-205. Read it with understanding.

---

*Or whatever measure of activity the "standard allowance" for acceptable production is to be expressed.

FIXED FACTORY OVERHEAD VARIANCES

(a) Budget variance . . . . (Budgeted fixed factory overhead - Actual fixed factory overhead)

(b) Volume variance . . . . (Normal volume[2] - Standard hours[2])Standard fixed factory overhead rate

---

[2] Or whatever the capacity concept being used, however expressed. Notice also that the volume variance formula given above represents the algebraic sum of the two fixed factory overhead variances shown at the bottom of page 207. Reasons for preferring the above formula are set forth on page 208.

Indicate, by the use of F or U designation, whether variances are favorable or unfavorable when you solve problems.

HOMEWORK PROBLEM NO. 1
Chapter 9

Calculating Variances

Assume the following data concerning one month:

Actual Manufacturing Costs		Standard Manufacturing Costs Applied	
Materials (1000 units @ $6)	6,000	Materials (1100 units @ $5.90)	6,490
Labor (3200 hours @ $2)	6,400	Labor (3250 hours @ $2.10)	6,825
Variable overhead	4,100	Variable overhead (3250 hours @ $1.20)	3,900
Fixed overhead	4,200	Fixed overhead (3250 hours @ $1.20)	3,900
	20,700		21,115

REQUIRED:*

Calculate (1) Price and efficiency variances for materials and labor.

*(2) Efficiency variance for variable factory overhead.

(3) Budget and volume variances for fixed overhead costs (hours of capacity for the month are 3400).

(4) Total up the seven variances to see if they are equal to the difference between actual and standard costs (21,115 - 20,700 = 415).

(*)Use the "best" method for calculating the overhead variances.

Appendix E.3

Course Outline for Accounting 102 - Spring Term, 1966

Field Test Project

Group 1: Lecture Group

Will be in attendance at all class meetings (MWF 1) with the professor, Dr. Cramer.

ASSIGNMENT AND OUTLINE SCHEDULE

Date	Period	Topic	Assignment
4/4	1	Lecture-Administrative	
4/6	2	Intro. to Mgmt. Acctg.	Chap. 1: Horngren* Chap. 1: Keller & Ferrara**
4/8	3	Accounting Concepts & Terminology	Chap. 2: Horngren Chap. 2: Keller & Ferrara Review: 2-2,5,6,12 K & F Do: 2-19 K & F
4/11	4	Lecture - Responsibility Accounting	Chap. 3: K & F Review: 3-2,3,4 K&F Do: 3-14, 17, 15 K & F
4/13	5	Cost-Profit-Volume Relationships	Chap. 3: Horngren Review: 3-1,3,4 H
4/15	6	Break-even Analysis	Chap. 3: Horngren Do: 3-8,9,13,14 H
4/18	7	Lecture-Cost Accounting Cycle	Chap. 4: K & F Review: 4-2,4,5,7, 8,10 K & F
4/20	8	Cost Accounting Cycle	Chap. 5: K & F Review: 5-4,5,6,7,8, 19 K & F

Date	Period	Topic	Assignment
4/22	9	Cost Accounting Cycle	Chap. 6: K & F Review: 6-2,7,9,10, 11,18
4/25	10	Lecture-Equivalent Units & Spoilage Calculations	Chap. 4: Horngren (especially Part II) and Handout Reading Assignment-Chap. 7.
4/27	11	Job Order Costing System	Chap. 7 pp. 131-142: K & F Do: 7-21 K & F
4/29	12	Process Costing System	Chap. 7 (remainder): K & F Do: Homework Problems No. 2 and 3 for Chapter 7 of K & F (handouts)
5/2	13	Lecture-Process Costing: Capacity Concepts	Chap. 7: K & F Do: Homework Problems 3 & 4 (handouts)
5/4	14	Process - Costing	Chap. 7: K & F Do: Homework Problem 5 for Chapter 7 K & F (handout)
5/6	15	EXAMINATION	ALL PREVIOUS ASSIGNMENTS
5/9	16	Lecture - Separation of Fixed and Variable Costs	Chapt. 7 pp. 193-198 and 207-216: Horngren; Handout Sheet Do: Handout Problem & 7-23, 25 H
5/11	17	Standard Costs	Chap. 8 pp. 171-184: K & F Review: 8-5,9,8,10, 11, K & F Do: 8-25 K & F
5/13	18	Standard Costs	Chap. 8 (remainder): K & F Review: 8-13,14,15, K & F Do: 8-26 K & F

Date	**Period**	**Topic**	**Assignment**
5/16	19	Lecture-Variance Analysis	Chap. 9 pp. 201-211: K & F Do: 9-17 and Handout Problem
5/18	20	Accounting for Standard Costs	Chap. 9 (remainder): K & F Do: 9-27, 30 K & F
5/20	21	Accounting for Standard Costs	Supplementary Reading Assignment for Chapter 9 Do: 9-19 and Handout Problem
5/23	22	Lecture-Direct Costing	Library Reserve Reading Assign. Johnson Paper of Direct Costing Do: 24-17 K & F
5/25	23	Lecture-Direct Costing	Chap. 24: K & F Do: 24-20 K & F and Handout Prob.
5/27	24	Cost Control and Flexible Budgeting	Chap. 10 & 11: K & F Review: 10-3,8,10, 11,21 K & F Do: 11-28 K & F
5/30	25	Lecture-Cost Control & Flexible Budgeting	Chap. 12: K & F Do: 12-18,20 K & F Review: 12-1,2,7 K & F
6/1	26	Lecture-Cost Data for Business Decisions	Chap. 13: K & F Review: 13-11,14 K & F
6/3	27	Lecture-Cost Data for Business Decisions	Chap. 18: K & F Do: 18-10,11,19 K & F Review: 18-20a K & F
6/6	28	Lecture-Budgeting and Financial Planning	Chap. 15: K & F Review: 15-2,7,9,11, 12,13 K & F Do: 15-18,19,22 K & F

Date	Period	Topic	Assignment
6/8	29	Lecture-Budgeting and Financial Planning	Chap. 16: K & F Review: 16-2,3,4,7, 8,12,13 K & F
6/10	30	Review 7 Re-analysis	Review
6/?	31	FINAL EXAMINATION	PREVIOUS MATERIAL: Emphasis on material of periods 13-30.

Field Test

Group 2: CAI Group

Will be in attendance at one class meeting per week (all Mondays of the term): two class meetings (equivalent time) will be spent at the teaching terminal in the CAI Laboratory (201 Chambers Building), with exception of those periods designated (periods 23, 26, 27, 29, and 30) during the week as "Lecture" when these students will meet in class as indicated at the regular class time. All regular class meetings are designated "Lecture" and the students should meet with the professor in class at those times (period 1 MWF).

Assignments and Course Outline:

The outline and assignments for Group 2 are the same as those for Group 1 with the following exceptions:

Date	Period	Topic	Assignment
4/4	1	Lecture-Administrative	C.A.I. Warm up and manapref scheduled at your convenience.
Week of:			
4/4 - 4/10	2,3		Complete Mana1
4/11-4/16	5,6		Complete Mana2
4/18-4/24	8,9		Complete Mana3 & Mana4 Homework Problem #1 for Chapter 3
4/25-5/1 5/2-5/8	11,12 &14		Complete Mana5 & Mana6 Period 15 - Examination
5/9-5/15	17,18		Complete Mana7
5/16-5/22	20,21		Complete Mana8
5/23-5/29	24		Complete Mana9

Remainder of the term, the class meets together in the regular scheduled class periods.

Accounting 102: Spring Term, 1966
Field Test Project

Group 3: Self-Study Group

Will be in attendance at one class meeting per week (all Mondays of the term); two class meetings (equivalent time - 2 and 1/2 hours) will be spent at the Curriculum Materials Center, EPC II, Room 401. It is important that this group spend a minimum of 2 1/2 hours per week in supervised self-study activities. The course outline and assignment schedule for Group 3 is the same as for Group 1 with the following schedule of additional reading assignments to be read during supervised self-study periods. All handouts will be placed in your folder.

Week of:	Additional Assignments to be read
4/4-4/10	N.A.A. Bulletin, June, 1963, Sect. 3, pp. 3-14 Chap. 1 in Beyer; Chap. 1, 2, & 3 of Anthony
4/11-4/16	Pp. 3-6; 27-34 in Bierman Chapter 12 in Welsch NAA Research Report Analysis of Cost-Volume-Profit Relationships. pp. 85-94 in Shillinglaw.
4/18-4/24	Chap. 4 in Horngren pp. 193-198; 251-260 Horngren Restudy Chap. 1-6 in Keller & Ferrara Appendix 101-110 Horngren
4/25-5/1	Chap. 3 Shillinglaw pp. 102-106; 112-131 Shillinglaw pp. 328-338 Shillinglaw
5/2-5/8	Complete Homework assignments Review for Examination Chap. 2 Wright
5/9-5/15	NAA Research Bulletin - Separation of Fixed and Variable Costs Chap. 1 and 4 in Gillespie
5/16-5/22	Chap. 2 & 3 in Gillespie Chap. 7 in Shillinglaw
5/23-5/29	Class on 5/25 Restudy Chap. 10 & 11 in K & F Chap. 8 in Shillinglaw

Remainder of Term: Meet with the entire class in lecture, period 1 MWF.

Appendix E.4

BOOKS AVAILABLE IN C.A.I. READING AND SELF-STUDY CENTER

Curriculum Materials Center - EPC II, Room 401

(1) Shillinglaw -- Cost Accounting: Analysis and Control

(2) Beyer, Robert -- Profitability Accounting for Planning and Control

(3) Wright, Wilmer -- Direct Costing

(4) Bierman, Harold -- Topics in Cost Accounting and Decisions

(5) Anthony, Robert -- Management Accounting: Text and Cases

(6) Gillespie, Cecil -- Standard and Direct Costing

(7) Welsh, Glenn -- Budgeting: Profit Planning and Control

(8) Horngren, Charles -- Cost Accounting: A Managerial Emphasis

(9) N.A.A. (N.A.C.A.) Research Reports:

"No. 37 on Direct Costing"
"Separation of Fixed and Variable Costs"
"Analysis of Cost-Volume-Profit Relationships"

(10) Other Materials Available:

Set of slides to accompany the Computer Assisted Instruction Course, and accompanying tapes. Tape segments (distinguished by loud beep tone) generally follow the slide numbers. A change of tapes is necessary for slides above no. 27.

Handouts, Exhibits, and Displays for Computer Assisted Instruction Course will also be available.

Appendix E.5

Sample of Introductory Management Accounting CAI Course

Sample Program

```
Label         Op Code      Argument

int6-2        rd           The material in this section is mainly
                           introductory in nature but should also
                           serve to acquaint you with the job order
                           costing system.  Press EOB when ready to
                           proceed.

              ld           1//s3

                                The first rd statement is
                                used to check the student's
                                preparation for this chapter.
                                The ld statement sets an internal
                                binary counter (switch) for later
                                branching and review.*

int6-3        qu           What are the two basic cost accounting
                           systems?

              ex

              fn           kw//3f

              ca           ,,job,,order,,and,,process

                                A kw function with f (feed-
                                back) accepts the response as
                                correct when it matches the
                                specified number of words in the
                                ca.  The feedback appears only
                                if the ca is matched (satisfied).

              ty           Correct!,,

gk1           ty           ,,The job order cost system, and the
                           process cost system are the two major
                           types.
```

---

*N. B. All material indented to this position represents author's explanatory comments about the stored computer program.

```
Label      Op Code    Argument

           un         Did you make a spelling error?  Try again.

           un         Incorrect.  Pages 131-142 of Keller and
                      Ferrara should have been read before
                      signing on for this course section.

           br         glk
```

If the student responds incorrectly twice, he is told that his preparation is unsatisfactory. He is then branched to <u>glk</u> where the correct answer is presented. He then proceeds to the next question.

```
int6-4     rd

           ty         Job order system is used if goods are
                      produced to customer specification;
                      process costing is used if goods are pro-
                      duced for stock.

retest6    rd

           ty         There are six basic entries in an actual
                      or historical cost system.  Entries must
                      be made for actual as well as applied
                      factory overhead.

           ld         0//s4

           ty         In the following questions we shall test
                      your knowledge of these basic journal
                      entries.  Use the basic form, including
                      the dr. and cr. designations.

           ad         -c1//c1

           ld         0//s5
```

The <u>ld</u> (load) statement sets internal switches; while the <u>ad</u> (add) statement clears an internal counter for the check sequence following.

```
           qun        What is the basic entry to record the use
                      of direct materials?
```

Label	Op Code	Argument
	nx	
	fn	pa0//6534//65
	ca	dr. work in process, cr. raw materials inventory
	ty	Okay

The partial-answer function (pa0) with feedback will check sequential strings of 6, then 5, and then 3 letters of the student's response and accepts the answer if 65% of these strings are matched exactly.

Label	Op Code	Argument
	nx	
	fn	pa0//43r//85
	wa	dr. direct materials
	ty	Your answer is not incorrect, but neither is it acceptable. What account is debited (or charged) to reflect direct materials and direct labor during the production process? Try again.
	un	Less than 65% correct. The correct answer is dr. work in process, cr. ________? Try again.
	ad	1//c1

The second partial-answer function checks for one half of the entry; if the student's response matches this half of the entry and not the entire ca, a hint is provided to the student for his next response. Note that a 1 is added to counter 1 for this error.

Label	Op Code	Argument
	nx	
	fn	pa0//653r//85

```
Label       Op Code     Argument

            wa          cr. accrued payroll

            ty          You have the credit portion correct, and
                        the debit portion was stated in the last
                        entry; both are debited directly to work
                        in process.  Enter the correct answer.

            ad          1//c1
```

The third partial-answer function is activated only if the first two are unsatisfied on any try.

```
            un          The entry records the direct labor costs
                        as a portion of the cost accumulated for
                        the goods as they are processed; it is
                        debited to the work in process account.
                        The amount of total wages is recorded by
                        the credit to accrued payroll.

            ad          1//c1
```

If none of the three preceding pa0 functions are satisfied, the first un statement is written. The student then receives a hint for each part of the entry. Again, 1 is added to counter 1 for this error.

```
            un          The answer is:  dr. work in process, cr.
                        accrued payroll.

            ad          1//c1

            br          int6-6
```

If the student's second response is entirely incorrect, he is given the ca and proceeds in the program. Again, a 1 is added to counter 1 for this error. At the end of the entire check sequence, the counter (c1) provides an accurate accumulation of the number of definite student errors. An appropriate feedback to the student is given on the basis of this information.

Appendix E.6

Exhibit 7B
(Chapter 7)

Recapitulation for Homework Problem No. 3
(mana6)

The work in process account, in effect, represents a modified COST OF PRODUCTION REPORT.

The account looks like this:

WORK IN PROCESS

Debit Side

Costs to be accounted for:

Beginning inventory of 4,000 units	
100% complete with respect to materials	$ 2,400
75% complete with respect to labor and overhead	1,500
Current costs	
Direct materials	22,000
Direct labor and factory overhead	18,000
TOTAL	$43,900

Credit Side

Costs accounted for as follows:

Units transferred to finished goods inventory (or next producing department)	$39,140
Costs included in ending work in process inventory (6,000 units)	
100% complete with respect to materials	3,300
50% complete with respect to materials	1,440
Rounding error	20
	$43,900

You have learned the procedures for process costing when only one department is involved and work in process is present at the beginning and end of the period. The average cost method was used for making the required calculations. The same problem will now be considered using the first in, first out method.

APPENDIX F

Engineering Economics CAI Course

Page No.

F.1 Course Outline for Engineering Economics 261

F.2 Sample of Engineering Economics CAI Program 263

Appendix F. 1

COURSE OUTLINE FOR ENGINEERING ECONOMICS

I. Text: Principles of Engineering Economy; Grant and Ireson, 4th Ed.

Supplemental Readings in:
II. Engineering Economy; Thuesen and Fabrycky, 3rd Ed..
III. Engineering Economy: Bullinger, 3rd Ed.
IV. Economic Analysis; Barish.
V. Cost Accounting; Matz, Curry, and Frank, 3rd Ed.
VI. Managerial Economics; Spencer and Siegelman, Revised Ed.
VII. Dynamic Equipment Policy; George Terborgh.
VIII. The Economics of Industrial Management; Rautenstraugh and Villers.

Group A - Lecture
Group B - CAI
Group C - Self-study

Date	Activity	Subject	Assignment	Problems
June 22	Pretesting			
24	Pretesting	Introduction to Engineering Economy	I-1, 2: II-1, 2, 3	
27	Class (A)	Accounting & Eng. Econ. ENGECON 101-102	I-10, 11; II-7, 8, 15; III-1, 2; IV-3, 14, 15, 16; V-2, 3: VIII-1, 2, 3; General VI-1, 2, 3, 4, 5: VIII-10, 11	
29	Class (A)			
July 1	Class (A)			
6	Class (A,B,C)			
8	Class (A)	Break-even Analysis ENGECON 103	I-15; II-11: III-9, 10, 11, 12, 13, 14; IV-33, 34: V-25; VI-6; VII-4; General VIII	
11	Class (A)			
13	Class (A,B,C)			

Date	Activity	Subject	Assignment	Problems
July 15	Class (A)	Time Value of Money ENGECON 104	I-3, 4, 5; II-4, 5 III-Appendix A; IV-5; VIII-8	—
July 18	Class (A)			
20	Class (A,B,C)			
22	Class (A)	Depreciation and Return on Investment ENGECON 105	I-10; Appendix-A; II-6; III-4; IV-6; VIII-9	
25	Class (A)			
27	Class (A,B,C)			
29	TEST (A,B,C)	To and including time value of money (CAI group including ENGECON 104)		
Aug. 1	Class (A)	Methods of Comparison ENGECON 106	I-6, 7, 8, 9, 13, 14, 16; II-10, 12; III-8, 13, 16, 17, 18, 22, 24; IV-9, 10, 11, 12; VIII-General Reading	
3	Class (A)			
5	Class (A,B,C)			
8	Class (A)	This period will be used to bring all groups to same level of work.		
10	Class (A)			
12	Class (A,B,C)			
15	Test			
Aug. 17	Class (A,B,C)	Minimum Cost Analysis	I-12; II-11; III-15; IV-18	
19	Class (A,B,C)			
22	Class (A,B,C)			
24	Class (A,B,C)	Special Problems		
26	Class (A,B,C)			
29	Class (A,B,C)			
31	Final			

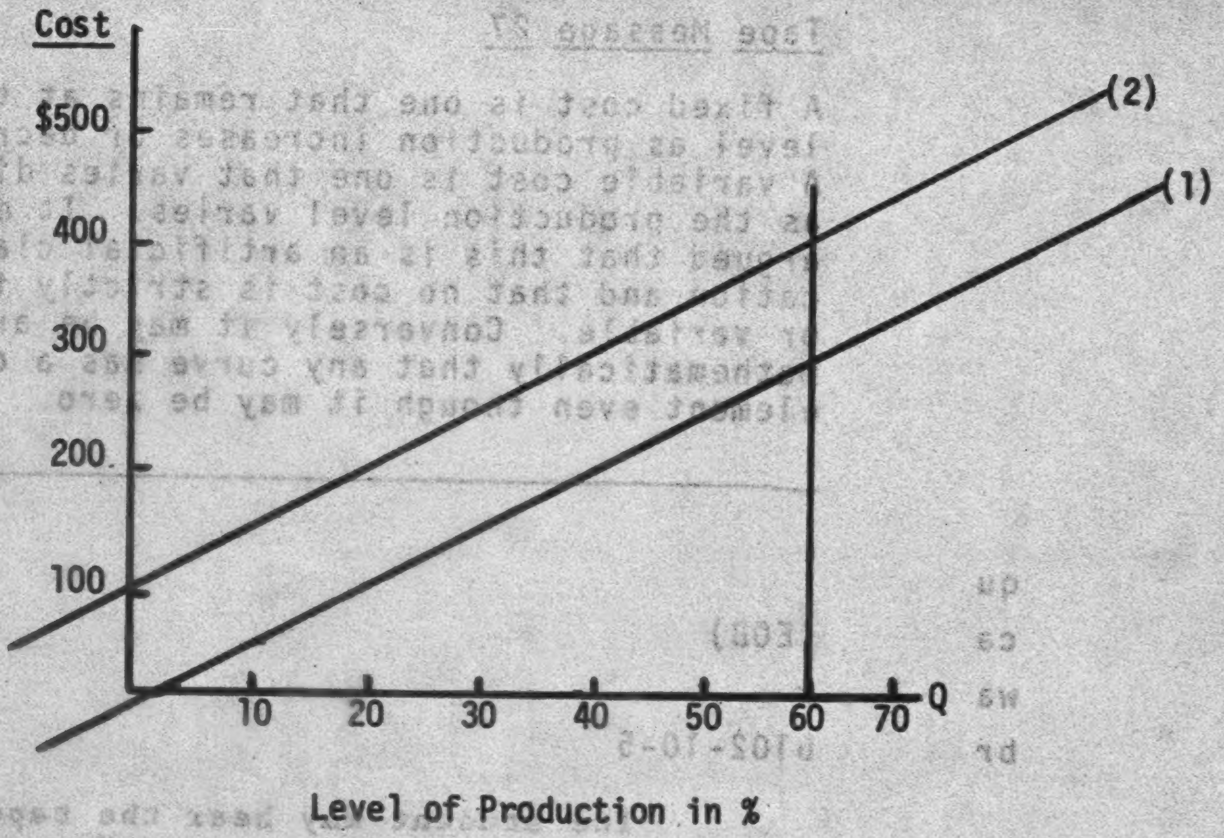
Appendix F.2

Sample of Engineering Economics CAI Program

Label	Op Code	Argument
b102-10-0	rd	
	fn	slide//27

Slide 27

ILLUSTRATION 02-V



---

	fn	wait//7

```
Label       Op Code   Argument
```

Student is allowed 7 seconds to examine the slide before the instruction proceeds. The contents of the slide will then be explained by tape messages and typewriter print out.*

```
b102-10-5   rd
            fn        tape//27
            fn        tape//28x
```

Tape Message 27

A fixed cost is one that remains at the same level as production increases or decreases. A variable cost is one that varies directly as the production level varies. It may be argued that this is an artificial classification and that no cost is strictly fixed or variable. Conversely it may be argued mathematically that any curve has a constant element even though it may be zero.

```
            qu
            ca        (EOB)
            wa        r
            br        b102-10-5
```

The student may hear the tape message again by typing a small "r" for repeat. Any other student response will allow the student to proceed with the instruction.

---

*N. B. All material indented to this position represents author's explanatory comments about the stored computer program.

```
Label      Op Code     Argument

b102-10-10  rd
            ty         In illustration 2-V equation (1) is C = 5Q
                       and equation (2) is C = 50 + 1.00.  Both
                       lines have a slope of 5 but they differ in
                       where they cross the ordinate.  Equation
                       (1) is said to be all variable cost; and
                       equation (2) is said to be a mixture of
                       fixed and variable costs.
            qu         In slide 27, what variable is plotted on
                       the abscissa?
            nx
            fn         kw//2
            ca         #level#production
```

The student response will be accepted if it contains the keywords level and production. The symbol # is a delimiter used to separate the keywords.

```
            ty         Correct.
            br         b102-35
            nx
            fn         kw//1
            aa         cost
            ty         No.  The cost is plotted on the ordinate.
```

The student's answer indicates that he has a misconception concerning the abscissa and ordinate. The next information he receives will be the first un below.

```
            un         Apparently you do not understand graphing
                       terminology.  You will now be given some
                       instruction on the meaning of abscissa and
                       ordinate.
            br         b102-32-0
```

Students who do not understand the meaning of abscissa and ordinate are branched to remedial instruction.

Label	Op Code	Argument
b102-35	qu	What is the dependent variable in graph 27?
	nx	
	fn	kw//1
	ca	#cost#Cost
	ty	Correct
	br	b102-41
	nx	
	fn	kw//1
	ca	#level#production$Level#Production
	ty	Wrong. The level of production determines the cost.
	un	You do not understand the meaning of independent and dependent variables. You must learn these meanings.
	br	b102-35-1

Students not understanding the meaning of independent and dependent variable are branched to remedial instruction.

Label	Op Code	Argument
b102-41	qu	At 50% capacity a certain cost is $3,000 and at 80% capacity, this same cost is $4,200. What is the equation of this cost curve?
	nx	
	fn	kwio//6
	ca	#c#=#40#q#+#100
	ty	Very good

This correct response is c = 40q + 100. The kwio function makes sure that the characters in the student's response are in the proper order and that there are no extraneous characters in the response. Careful programing allows variation in the format of the student's response, (i.e., capitalization and spacing are not considered).

```
Label     Op Code   Argument

           br       b102-42
           un       Wrong.  Did you use the correct equation
                    for slope (y = mx + b) and adapt it to
                    this special case?  Try again.
           un       Wrong.  Let us investigate the problem in
                    more detail.
           br       b102-41-1
```

Students who are unable to obtain the correct response in two attempts are branched to appropriate instruction.

```
b102-42    qu       What is the cost of this operational func-
                    tion at 60% capacity?
           nx
           fn       ed//#//,//#// //#3400//3400.//3400.0//3400.00
```

If the student uses a comma in his response to indicate the thousands position, the comma is edited and only the numerical characters are compared. Spacing and the # sign are also edited from the student's response. If the student responds with either 3400., 3400.0, or 3400.00, his answer is replaced with 3400.

```
           ty       Correct.  C=40 x 60) + 1000 = 3400
           un       Incorrect.  Are you using a slope value of
                    40?
           un       Still not correct.
                    C=(40 x 60) + 1000 = 3400
           ty       You need more practice.
           br       b102-42-1
```

Students having trouble are branched to practice problems.

```
b102-43-1  rd
```

APPENDIX G

Modern Mathematics CAI Course

Page No.

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G.4 Sample of Modern Mathematics CAI Program. 291

Appendix G.1

Math 200

OUTLINE OF TOPICS
Spring Term, 1966

Date	Wk.		CAI Segment
April 5	1	Test	
April 7	2	Sets	Mavmath1
April 9	3	Relations	Mavmath2
April 12	4	Discussion	
April 14	5	Exponents; numeration	Mavmath3 and 4
April 16	6	Number bases	Mavmath5
April 19	7	Number bases	Mavmath5
April 21	8	Discussion	
April 23	9	Addition	Mavmath6
April 26	10	Addition	Mavmath6
April 28	11	Discussion	
April 30	12	Subtraction	Mavmath7
May 3	13	Subtraction	Mavmath7
May 5	14	Discussion	
May 7	15	Multiplication	Mavmath8
May 10	16	Multiplication	Mavmath8
May 12	17	Discussion	
May 14	18	Midterm	
May 17	19	Division	Mavmath9
May 19	20	Division	Mavmath9
May 21	21	Integers	Mavmath10
May 24	22	Discussion	
May 26	23	Fractions	Mavmath11
May 28	24	Fractions	Mavmath11
May 31	25	Discussion	
June 2	26	Decimals	Mavmath12
June 4	27	Ratio & %	Mavmath13
June 7	28	Real numbers	Mavmath14
June 9	29	Discussion	
June 11	30	Test	

Appendix G.2

Report on the Development of a Test for Modern Mathematics

The test was developed to serve as a pre- and post-test measure for the experimental course on modern mathematics (modmath) via Computer Assisted Instruction. The modmath course consists of 14 chapters, including concepts of sets, relations, numeration systems, operations on whole numbers, integers, rational numbers, and real numbers. The test was designed to provide a representative sampling of content from each of these chapters.

Content validity is postulated on the following bases:

1) An outline of concepts which are developed in each of the 14 chapters of the modmath course was prepared. A tentative proposal was made of the number of knowledge, understanding, and application items which should be written for each chapter for initial trial. A group of approximately 250 items was prepared, using the concept outline and the proposal of types of items.

2) Texts in the field of mathematics education were used in developing the course, and these were consulted in writing the test items. Among these texts were:

a) Mueller, Francis J. *Arithmetic, Its Structure and Concepts*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964.

b) Peterson, John A. and Hashisaki, Joseph. *Theory of Arithmetic*. New York: John Wiley and Sons, Inc., 1963.

c) Swain, Robert L. and Nichols, Eugene D. *Understanding Arithmetic*. New York: Holt, Rinehart and Winston, Inc. 1965.

d) Ward, M. and Hardgrove, C. E. *Modern Elementary Mathematics*. Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1963.

e) Webber, G. Cuthbert and Brown, John A. Basic Concepts of Mathematics. Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1963.

f) Twenty-ninth Yearbook: Topics in Mathematics for Elementary School Teachers. National Council of Teachers of Mathematics, 1964.

3) Dr. C. Alan Riedesel, Associate Professor in the Department of Elementary Education, The Pennsylvania State University, and co-author of the modmath course, read all items for applicability to course content. Approximately 50 items were discarded, leaving a 206-item trial test. The final 50-item test was drawn from these items, with selection on the basis of item analysis and content sampling for representativeness.

The analysis chart for items on the trial test follows.

The trial test was administered in two sessions to 40 students enrolled in one section of El. Ed. 326 (Teaching Arithmetic in the Elementary School) during the winter term. The test was administered during the regular afternoon class periods. This group was chosen on two bases: 1) These students had completed a course comparable to modmath (Math. 200). Their knowledge of the concepts taught would provide a basis for analyzing the usefulness of the items. 2) Availability of these students for the three to four hours necessary to complete the 206-item test.

Two students were absent on the second day, so that data is based on 38 students. This small number is definitely a limitation, particularly in obtaining discrimination indices. The appropriateness of this sample for analyzing a test for a modmath course is questionable for several other reasons. The fact that the students had completed the mathematics course previously meant that this test was for them a measure of long-term retention of concepts. They had taken Math. 200, not modmath, and had had modmath test

											Re-evaluation				
Modmath Content	Modmath chapter	# of qu's	% of Total	Approx. # of major concepts (in outline)	% of Total	# of Trial items	Know-ledge	under-standing	appli-cation	# of final items	# of trial items	K	U	A	# of final items
Sets	1	68	7	11	5	10	2	3	5	3	20	5	6	9	5
Relations	2	47	5	9	4	10	2	3	5	2	10	2	3	5	3
Exponents	3	38	4	9	4	10	3	3	4	2	40	11	18	11	10
Numeration System	4	22	2	17	8	10	2	3	5	2					
Other Bases	5	78	8	19	9	20	3	5	12	4					
Addition	6	121	12	20	10	20	4	6	10	5	60	16	29	15	15
Subtraction	7	99	10	20	10	20	4	6	10	5					
Multi-plication	8	117	2	20	10	20	4	6	10	5					
Division	9	79	8	20	10	20	4	6	10	5					
Integers	10	69	7	8	4	10	3	2	5	4	10	3	2	5	2
Fractions	11	117	12	24	12	20	4	6	10	4	50	16	21	18	12
Decimals	12	66	7	10	5	10	2	3	5	3					
Ratio & Percent	13	36	4	15	7	10	5	3	2	3					
Real Numbers	14	68	7	7	3	10	5	3	2	3	10	5	4	2	3
		1025		209		200	47 25%	58 30%	95 45%	50		58 29%	83 41%	65 32%	50

several different instructors. In addition, their motivation might be questioned, since they knew that the test would not affect their grades. (Their attitude nevertheless appeared to be very cooperative, which might be substantiated by the number of items which all completed. They accepted the test as a possible diagnostic aid: it would indicate areas in which they needed review.)

Answer sheets were machine-scored by Examination Services, and the item analysis was performed at the Computation Center.

The range of scores on the 206-item test was from 74 to 168, a 94-point range. The mean equalled 122.05, with a variance of 425.83 and a standard deviation of 20.64. Mean difficulty of the items was .592. The distribution of the test items in terms of the percentage of students passing them was:

percent passing	number of items
0 - 19	14
20 - 39	33
40 - 59	51
60 - 79	58
80 - 100	50

The distribution of the test items in terms of item-total score correlations was:

correlations	number of items
negative - .10	45
.11 - .30	60
.31 - .50	65
.51 - .70	29
.71 - .90	7
.91 -1.00	0

The average item-total score correlation was .304. This is perhaps a reflection of the scope of the content on which the test is based. Estimated interitem correlation is .092, with a standard error of correlation of .164.

The distribution of scores is presented on the next pages in ungrouped and grouped form.

The charts which follow show pertinent information, taken from the computer sheets, for each item on the trial test. The Kuder-Richardson 20 reliability estimate is .916. No other reliability data is available on the trial test. If a more approporiate sample had been available, other estimated tests of reliability would have been helpful. No attempt was made to compute the reliability for chapter or subtest scores, since total test performance is to be the criterion for usefulness. Some analysis of the factors present in the test, plus analysis of the reliability of the subtest items, will be made after use of the 50-item test.

A set of criteria was developed for choosing 50 items from the 206 trial test:

1) Difficulty index
    a) .50 to .70
    b) .40 to .49, and .71 to .80
2) Item-total score correlation (discrimination index)
    a) .70 to 1.00
    b) .40 to .70
3) Lower fifth-upper fifth comparison
4) Content balance

It was also found necessary to estabilish priorities for choosing items:

1) Difficulty index a) - discrimination index a)
2) Difficulty index a) - discrimination index b)
3) Difficulty index b) - discrimination index a)
4) Difficulty index b) - discrimination index b)
5) Difficulty index a) - lower/upper fifth comparison
6) Difficulty index b) - lower/upper fifth comparison

Frequency distribution of original scores: (N = 38)

74	/
75	
76	
77	
78	
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81	
82	
83	/
84	
85	
86	
87	
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89	/
90	
91	/
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97	
98	
99	/
100	
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103	//
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165	/
166	
167	
168	/

Frequency distribution of grouped scores: (N = 38)

71	- 80	/
81	- 90	//
91	- 100	//
101	- 110	/////
111	- 120	//////
121	- 130	/////////
131	- 140	///////
141	- 150	////
151	- 160	
161	- 170	//

Following this, cruciality of content plus reasonable representative sampling by chapters were considered. Re-analysis disclosed duplications of concepts in a few cases, and other priority items replaced these.

The next table shows the pertinent information about each of the items which compose the 50-item test. A summary by subsections is also included.

The average difficulty index of the final test is .670, which is slightly higher than the index for the initial test. This may be less ideal, but it seemed more desirable to have a representative sampling. The levels which the indices will assume when the test is used following a modmath course is, of course, a matter of conjecture.

The Spearman-Brown formula was used to estimate the reliability of a final test which is one-fourth the length of the initial test: the expected r is .732. This, however, presumes the same type of sample.

Analysis of the value of the distractors resulted in some rewriting. This was not done in all cases, since sometimes no other distractors were plausible, and since it is hypothesized that with other samples the present distractors might serve better.

The test will be used during the spring term field testing of modmath. Another test, consisting of 40 items with difficulty indices of .80 to 1.00, has also been selected from the original pool of 206 items. This will serve as a means of selecting equivalent groups for the field test.

Report on the development of a test for modern mathematics

Chapter-content	# of items written	range of item difficulty	range of item discrimination	# of items with difficulty between		range of discrimination for these items	#of items with .40-.80 difficulty and .40+ discrim.	# of items needed
				.50-.70	.40-.80			
1-Sets	22	.079-.921	-.009-.684	7	14	-.009-.609	3	5
2-Relations	10	.132-.974	.089-.662	2	4	.208-.464	1	3
3-Exponents 4 Decimal & 5 other bases	41	.158-1.000	-.056-.779	15	22	.033-.725	11	10
6-7-8-9 Operations with whole numbers	60	.053-1.000	-.086-.845	18	32	-.086-.580	9	15
10-Integers	10	.316-.921	-.088-.890	2	5	.068-.550	2	2
11-12-13 Rational numbers	53	.158-.974	-.248-.818	7	23	-.003-.651	10	12
14-Real numbers	10	.211-.816	-.010-.707	1	3	.202-.461	1	3

Mean difficulty = .592

Average item-total score correlation = .304

Estimated interitem correlation = .092

KR_{20} = .916

Range of scores: 74 - 168

Test mean = 122.05

SD = 20.64

Information about each item on the final 50-item test

chap.	Item #	KUA	topic	diff.	discrim.
1	6	K	subsets: inclusion notation	.789	.464
	10	U	setbuilder: intersection	.684	.609
	18	A	Venn diagram: intersection, U	.789	.494
	21	A	union	.763	.323
	23	A	subtraction: set of integers	.605	.290
2	24	K	Venn diagram: cardinal number	.974	.121 (rewritten)
	31	A	"T" relation : properties	.474	.208
	33	A	"sameness" relation	.789	.464
3 4	38	K	exponents: division	.658	.480
5	41	U	expanded notation: base five	.579	.540
	44	U	exponents: multiplication	.500	.508
	46	U	expanded notation: letters	.684	.459
	49	U	largest base six number	.737	.462
	56	K	ordinals	.684	.491
	63	K	counting: base eight	.684	.612
	67	A	expanded notation: base six	.553	.403
	69	U	base two to ten	.605	.489

chap.	Item #	KUA	topic	diff.	discrim.
	73	A	base two: addition	.737	.725
6	75	K	identity: addition	.447	.329
7 8	77	K	terminology	.579	.456
9	81	K	inverse: addition	.605	.201
	89	U	mod 9: addition	.447	.290
	91	A	properties: assoc., distrib.	.605	.264
	98	A	equal additions: subtraction	.474	.542
	102	A	base five: subtraction	.579	.482
	106	U	multiplication: distrib.	.605	.400
	111	U	multiplication: regrouping	.711	.461
	112	U	multiplication: distrib.	.684	.580
	117	A	multiplication: lattice	.658	.162
	123	K	exact division	.737	.539
	127	U	repeated subtraction: division	.447	.548
	132	A	quotient estimation	.605	.519
	133	A	partition division	.553	.383
10	137	K	member of set: integers	.711	.550
	141	A	integers: subtraction	.763	.522
11	144	K	definition: fractions	.763	.421
12 13	146	K	equivalence class	.605	.575
	148	K	exact divisors	.789	.620
	158	A	LCM	.474	.477
	166	K	largest decimal	.553	.651
	172	U	fractions: commut.	.816	.730
	176	U	decimals: multiplication	.711	.509
	178	U	decimals: line relation	.474	.484

chap.	Item #	KUA	topic	diff.	discrim.
	189	U	ratio	.737	.597
	193	A	percent	.553	.361
	195	A	ratio	.684	.587
	196	A	rate-pair problem	.579	.544
14	200	K	non-terminating dec.	.474	.202
	203	U	nested intervals	.816	.707
	206	A	rounding	.553	.461

Report on the development of a test for modern mathematics

Chapters	Original analysis			Re-evaluation			Final form			Average difficulty	range of difficulty	average discrim.	range of discrimination
	K	U	A	K	U	A	K	U	A				
1	2	3	5	5	6	9	1	1	3	.726	.605-.789	.436	.290-.609
2	2	3	5	2	3	5	1	0	2	.746	.474-.974	.264	.121-.464
3-4-5	8	11	21	11	18	11	3	5	2	.642	.500-.737	.517	.403-.725
6-7-8-9	16	24	40	16	29	15	4	5	6	.582	.447-.737	.410	.162-.580
10	3	2	5	3	2	5	1	0	1	.737	.711-.763	.536	.522-.550
11-12-13	11	12	17	16	21	18	4	4	4	.645	.474-.816	.546	.361-.730
14	5	3	2	5	4	2	1	1	1	.614	.474-.816	.457	.202-.707
	25%	30%	45%	29%	41%	32%	30%	32%	38%	.670		.452	

Criteria used to select items:
1) Difficulty index
    a) .50-.70
    b) .40-.49, and .71-.80
2) Item-total score correlation
    a) .70 to 1.00
    b) .40 to .70
3) Upper-lower fifth comparison
4) Content

Appendix G.3

Sample of Study Guide

Math 200

Study guide 6 -- Addition

1. In Peterson & Hashisaki: exercise 5.2, page 83, #2, 3, 4, 5
   exercise 5.5, page 88, #2(a, b), 6, 8
   exercise 5.6, page 92, All
   exercise 5.11, page 104, #1, 2(a,c), 4, 7(a)

2. Which of the following sets of numbers is (are) closed under the operation of addition?
   - (a) {5, 10, 15, 20, ...}
   - (b) {even natural numbers}
   - (c) {odd natural numbers}
   - (d) {1, 11, 21, 31, 41, 51, ...}
   - (e) {0, 2, 4, 6, 8, ..., 20}

3. By means of a number line, show that
   - (a) 5 and 7 are commutative under addition
   - (b) 4, 6, 3 are associative under addition
   - (c) 4, 3, 0 are associative under addition

4. Give three nonmathematical illustrations of commutativity; three nonmathematical illustrations of lack of commutativity.

5. Give one nonmathematical illustration of associativity; of lack of associativity.

6. Given the set of natural numbers and the operation * (pronounced "star") which means "add the numbers it combines and increase that sum by one;" e.g., 6 * 4 = 11, 3 * 0 = 4, 3 * 2 * 5 = 12. Is the set of natural numbers
   - (a) closed with respect to *?
   - (b) commutative with respect to *?
   - (c) associative with respect to *?

Study Guide 6 -- continued

7. Add by the "scratch" method:

(a) 6,429
+2,857

(b) 4,387
+9,774

8. Find the excess of nines for the following numbers by adding the digit-values. Check your work by dividing by 9.

(a) 71
(b) 35
(c) 88

9. Add the following and check by three checks: commutative, associative, excess of nines.

(a) 8,637
5,922
3,872
6,795

10. Add 632 + 879 + 643. Now make your answer incorrect by (a) switching the digits around; (b) adding 27 to the answer. "Check" your problem with these two incorrect answers by the excess of nines method. How do you account for what happens?

11. In the number sentences below, tell whether $A < B$, $A > B$, or $A = B$.

(a) $14 + A = B + 10$
(b) $26 + A = B + 34$
(c) $14 + A > 27 + B$

12. Given the infinite set of counting numbers which are symbolized, in order, as m, t, s, k, v, w, r, b, x, q, . . ., where m is the initial counting number and its successor is t, whose successor is s, etc.

(a) Complete the following addition table:

+	m	t	s	k
m		s		
t				
s				
k				b

Study Guide 6 -- continued

(b) Is the set $\{m, t, s, k, \ldots\}$

- (i) closed under addition?
- (ii) commutative under addition?
- (iii) associative under addition?

Give one example to illustrate each of your answers.

Read in Peterson & Hashisaki, pp. 81-92, 100-103.

Appendix G.4

Sample of Modern Mathematics CAI Program

Label	Op Code	Argument
5-5	qu	When we add 1 to 99, we have 9 tens and 10 ones. The 10 ones form 1 ten, so we have 10 tens. How do we write "10 tens" with numerals?
	ca	100
	ty	Correct
	un	What number comes after 99? Type it in digits.
	ad	-1//cl
		This coding illustrates the use of counters; the number of incorrect responses is being accumulated and stored for a branching decision.*
5-6	qu	The 1 is now in the hundreds place. That means we have a three-place numeral. With what numeral do we first use four places?
	nx	
	fn	kw//1
	ca	. 1000 .ne thousand. 1,000
		This keyword function will accept as correct any variation of the correct answer - 1000, one thousand, One thousand, or 1,000. The number of additional words which are typed by the student - as, for example, when he answers with a complete sentence - is immaterial.

---

*N. B. All material indented to this position represents author's explanatory comments about the stored computer program.

Label	Op Code	Argument
	ty	Correct
	un	Think of the largest 3-place number - right! 999. Now add 1 to this, type your answer.
	ad	-1//cl
5-7	rd	
	ty	Look at the slide.
	rd	
	fn	slide//37
	fn	tape//34
	fn	tape//35x

A slide which contains a chart of the place value system is displayed. While the student looks at it, a tape message is played, calling attention to certain aspects of it. The x following the second tape number merely indicates positioning of the following tape; it is not played at this time.

Label	Op Code	Argument
5-7-b	rd	
	ty	Notice the relationship involved in the place value system of base ten.
	ty	Since we cannot at this point write exponents on this machine, we will write its meaning in words.
	ty	Thus 1 = ten to the zero power 10 = ten to the first power 100 = ten to the second power, or ten squared
	qu	What is 1000 expressed as a power of 10?
	nx	
	fn	kw//2
	ca	.en.third. 10 .3.cubed

Here the keyword function will look for 2 words; thus it will accept 10 to the third power, 10 to the 3rd power, ten cubed, and several other variables.

Label	Op Code	Argument
	ty	Ten cubed is correct.
	un	Notice the order of the exponents (0,1,2). Therefore, what would come after 10 squared or 10 to the second power?
	ad	-1//cl
	un	The correct answer is "10 to the third power." Type this.
	ad	-1//cl
5-8	qu	How would the next place be expressed in terms of exponents? (Since exponents cannot be typed in this chapter write it out in words.)
	nx	
	fn	kw//2
	ca	. 10 .en.fourth.4
	ty	Ten to the fourth power is correct.
	un	A new place is reached with 10,000. This is 10 x 10 x 10 x 10. Written in exponential form, this is "10 to the _____ power."
	ad	-1//cl
	un	Type "10 to the fourth power."
	ad	-1//cl
	rd	
	br	reml//cl//4

This is a statement regarding a branching decision. If the contents of counter 1, with which incorrect responses have been recorded, is greater than 4, then the student is branched to reml. That is, if the student has missed more than 4 questions, some remedial work is suggested. If he missed fewer than 4 of the review questions, he is branched on in the program.

```
Label    Op Code   Argument

         br        5-9
reml
         rd        You could profit from some review of our
                   numeration system.  Read Mueller, Chapter
                   3.  Then press EOB
5-9
         fn        slide//38x
         fn        tape//35
         fn        tape//36x
5-9-a    qu        If you want to hear the tape again, type r.
                   If not, just press EOB.
         ca        (EOB)
         cb        p
         wa        r
         wb        R
         br        5-9
```

Many tapes contain information which the student might need to listen to more than once. He is allowed to choose whether he wants the repetition or not.

```
         un        Type r or press EOB
5-9-b    rd
         fn        slide//38
         fn        wait//8
```

This "wait" function indicates that the next statement will not be typed until the slide has been in position for 8 seconds.

```
5-10     qu        Suppose a group of persons in an isolated
                   location were all born with four fingers
                   on each hand.  What number base would these
                   people probably have used?

         nx
```

```
Label     Op Code   Argument

          fn        kw//l
          ca        . 8 .ight
          ty        Correct
          fn        slide//39x
          nx
          fn        kw//l
          wa        .4.our
          ty        They might use base four - what other base
                    might they use?
```

When wrong answers can be anticipated, specific clues or hints can be given to show why the answer is incorrect, or, as in this case, to help the student answer correctly.

```
          un        Think it through more carefully:  How many
                    fingers do we have in all?  What base do
                    we use?  What base would an eight fingered
                    person probably use?  Now type your answer.

          un        The answer is 8.  Type 8.

5-11      qu        Remember that base ten has ten single digits.
                    But how many will base eight have?

          nx
          fn        kw//l
          ca        .ight. 8
          ty        Correct
          un        Base eight has eight single digits.  Type
                    eight.

5-12      rd
          ty        Let's try counting in base eight.  1, 2, 3,
                    4, 5, 6, 7, - and we need a digit to
                    represent the cardinal number of the empty
                    set - 0.  That's eight digits.

          ty        If we add 1 to 7, we reach the sum 8 - but
                    8 is not a digit in base eight.
```

```
Label     Op Code     Argument

          ty          Recall what happens under the same circum-
                      stances in base ten.

          qu          Now write the numeral which means "one of
                      the base and zero ones," in base eight.
```

When more than 3 or 4 lines are to be typed to the student, they are generally presented in segments, using the <u>ty</u> (typeout) function.

```
          nx

          fn          kw//1

          ca          , 10

          ty          Correct

          ca          10

          ty          10 (eight) is more definitive.  However,
                      we will allow either form as correct -
                      just remember which base your answer is
                      in!

          un          The number after 7 in base eight is 10
                      (eight), which means "one group of the
                      base (eight) and zero ones."  Type 10
                      (eight).

5-13

          rd

          fn          tape//36

          fn          tape//37x

          fn          slide//39

          fn          tape//37

          fn          tape//38x

          fn          slide//40x

5-13-a    qu          Type r or press EOB.

          ca          (EOB)

          cb          p

          wa          r
```

```
Label     Op Code   Argument
          wb        R
          br        5-13
          un        Type r or press EOB.
5-14      rd
          ty        Now study the number line on the next slide.
          rd
          fn        slide//40
          qu        What number should appear after 17 (eight)?
          nx
          fn        kw//1
          ca        , 20
          ty        Correct.
          ca        20
          ty        Correct - remember it is 20 in base eight.
          nx
          fn        kw//1
          wa        , 18
          ty        Do we use the numeral 8 in base eight?
                    One of the base and 8 more would equal 2
          of        of the base.  How should 2 of the base be
                    written?
          un        The numeral after 17 (eight) would represent
                    2 of the base.  How should 2 of the base be
                    written?
          un        The numeral after 17 (eight) would be 2 of
                    the base or 20 (eight).  Type 20 (eight).
```

Several un statements are sometimes used to give increasing specific clues or hints. Generally, the final un statement will tell the student the correct answer.

```
5-15      qu        What numeral will follow 20 (eight)?
          nx
          fn        kw//1
```

```
Label     Op Code   Argument
          ca        , 21
          ty        Correct
          ca        21
          ty        Correct - 21 in base eight.
          un        The correct answer is 21 (eight), meaning
                    "two of the base and one more." Type the
                    correct answer.

5-16

          qu        Notice the x's on the slide.
                    If you were to divide them into groups of
                    eight, how many groups of eight would there
                    be?

          nx
          fn        kw//1
          ca        . 3 .hree
          ty        Correct.
          br        5-17
          un        Incorrect.
          br        5-16-1
```

If the student types the correct answer, he is branched on to question 17. If, however, he answers incorrectly, he is branched to a series of questions, varying in length from 2 to 10, for additional help.

```
5-16-1    qu        If you were counting the x's in base 10,
                    how many x's would there be in all?

          nx
          fn        kw//1
          ca        , 25
          un        The correct answer is 25 (ten). Type it.
5-16-2    qu        How many 8's are in 25 (ten)?
          nx
```

```
Label     Op Code   Argument

          fn        kw//1
          ca        ,hree, 3
          un        There are three 8's in 25 (ten).  Type 3.
5-17      qu        How many ones are left over?
          nx
          fn        kw//1
          ca        ,ne, 1
          un        The correct answer is 1 or one.  Type it.
5-18      qu        How would you represent the number in base
                    eight associated with the x's?
          nx
          fn        kw//1
          ca        , 31
          ty        Correct
          ca        31
          ty        Correct - 31 in base eight.
          un        How many groups of the base (eights) are
                    contained in the x's?  How many ones?
                    Try again.
          un        There are 3 groups of the base (eight)
                    and 1 one.  Type 31 (eight).
5-18-a    rd
          fn        slide//42x
5-19      qu        Write the numeral in base eight which means
                    "five eights and seven ones."
          nx
          fn        kw//1
          ca        , 57
          ty        Correct.
          un        The correct answer should be 57 (eight).
5-20      rd
          ty        Recall the progression of place values in
                    base ten-ones, tens, hundreds, etc.
```

```
Label       Op Code    Argument

            ty         In base eight, place values are, of course,
                       based on powers of eight.
            ty         Study the place value chart on the next slide.
            rd
            fn         slide//42
            fn         tape//38
            fn         tape//39x
            qu         What numeral should be inserted in place
                       of the A in the chart?
            nx
            fn         kw//1
            ca         ,ixtyfour, 64
            ty         Correct.
            un         The correct answer should be 64.  Type it.
5-21        qu         After 8 x 8 would come 8 x 8 x 8.  What
                       numeral should be inserted in place of B?
            nx
            fn         kw//1
            ca         ,512
            ty         Right!
            un         8 x 8 x 8 or 8 cubed = 512.  Type 512.
5-21-a      rd
            fn         slide//43x
5-22        qu         When working with other bases, we frequently
                       change a number from one base to another.
                       What is the value of 37 (ten) in base eight?
            nx
            fn         kw//1
            ca         , 45
            ty         Correct.
            br         5-23
            ca         45
            ty         Correct, 37 (ten) = 45 (eight)
```

```
Label     Op Code   Argument

          br        5-23
          un        Incorrect.  Let's break the problem down
                    into smaller steps.  If however, you
                    realize how to find 37 (ten) in base
                    eight, type in the correct answer at any
                    point.
          br        5-22-1
5-22-1    qu        Look again at 37 (ten).  We are looking for
                    a way of regrouping it in terms of eights
                    or powers of eight.  What is the largest
                    power of eight represented in 37 (ten)?
          nx
          fn        kw//2
          ca        , 8 ,ight,irst
          nx
          fn        kw//2
          ca        , 8 , 1 ,irst
          ty        Correct.
          nx
          fn        kw//1
          ca        , 45
          ty        Good for you!  37 (ten) = 45 (eight)

                         Notice that 45 is the answer to
                    the original question, "What is the
                    value of 37 (ten) in base eight?"
                    If the student realizes his error at
                    this point, or during any of the
                    succeeding remedial steps, he can
                    simply type the correct answer  and
                    will be branched out of the remedial
                    sequence.
          br        5-23
          un        The correct answer is "8 to the first power."
                    Eight raised to the second power or 64, is
                    not contained in 37.  Type "8 to the first
                    power."
5-22-2    qu        How many groups of 8 are there in 37 (ten)?
```

```
Label     Op Code     Argument

          nx
          fn          kw//l
          ca          ,our, 4
          ty          Correct
          nx
          fn          kw//l
          ca          , 45
          ty          Good for you!  37 (ten) = 45 (eight)
          br          5-23
          un          8 goes into 37 four times.  Type four.
5-22-3    qu          Make a place value chart for base eight on
                      a piece of scrap paper.  Write 4 in the
                      eights column.  What is the remainder when
                      you subtract 4 eights from 37 (ten)?
          nx
          fn          kw//l
          ca          ,ive, 5
          ty          Correct
          nx
          fn          kw//l
          ca          , 45
          ty          Good for you!  37 (ten) = 45 (eight)
          br          5-23
          un          4 eights = 32.  37 - 32 = 5.  Type 5.
5-22-4    qu          Since there are no eights in this remainder,
                      this indicates the number of ones remaining.
                      Write 5 in the ones column.  Now read the
                      number.  What is 37 (ten) in base eight?
          nx
          fn          kw//l
          ca          , 45
          ty          Correct - 37 (ten) = 45 (eight)
          un          37 (ten) = 45 (eight)  Type 45 (eight)
5-23      qu          What is 75 (ten) in base eight?
```

APPENDIX H

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Appendix H.1

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Management Accounting Via Computer-Assisted Instruction

By JOE J. CRAMER, JR.

THE RAPID RATE of technological change in the American economy has traditionally been associated with manufacturing processes, improvements of products, etc. Educational psychologists have recently made explicit attempts to apply the fruits of this technological advance to teaching situations, including the industry programs of training new employees and re-educating existing personnel.

During the past year the author of this article has been engaged in a research project the purpose of which is to develop an experimental program for teaching basic management accounting through the use of a computer.[1]

Computer-assisted instruction may be characterized as an automated instructional process with the following features: (1) a computer program, (2) a centralized high-speed computer which is actually a high-speed data processing system—a network of machine components—and (3) student stations which are tied to the high-speed computer.

The computer must be capable of accommodating a large number of students simultaneously. The instructor, in the traditional sense of the word, is involved with the program in the sense that he may actually prepare it or approve its use.

The philosophy or hypothesis underlying such a learning-teaching situation is quite simple. First, in view of the present mass of people to be educated all teaching cannot be done by human beings. Furthermore, the teacher can emphasize his finer points, leaving many procedural aspects to the computer. A brief description of the development of a basic management accounting course for computer presentation is given below.

---

[1] The overall project is entitled "Development and Presentation of Four Different College Courses by Computer Teleprocessing." Two major purposes of this research are (1) to study the feasibility of phasing computer-assisted instruction into the instructional program of a large state university and (2) to field test the computer-assisted instruction courses in official college classes with typical students and other normal educational parameters. Courses are being developed in engineering economics, modern mathematics, audiology and basic management accounting. The project is supported by the United States Office of Education under the provisions of Title VII of the National Defense Education Act of 1958, Project No. (OE-4-16-010). The equipment used is the IBM 1410 computer configuration at the Thomas J. Watson Research Center, Yorktown Heights, New York. Completion date for the project is scheduled for June 30, 1966. I am especially appreciative for the efforts expended by Charles Hugh Smith who served as my graduate assistant during the past year and to Harold Mitzel and Kenneth Wodtke, co-directors of the project.

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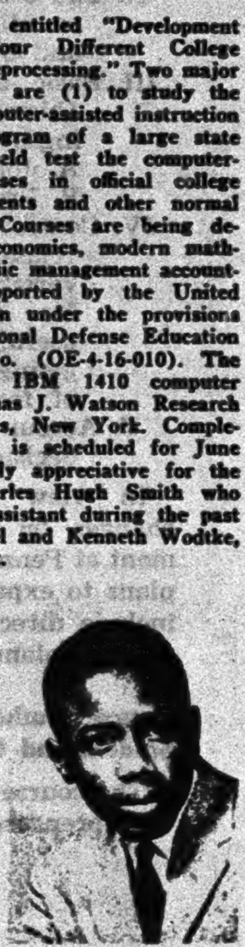

Course Content

The course is a one-term course formally classified as basic management accounting. As developed for computer presentation, certain portions of the course have been expanded by "Supplementary Reading Assignments," prepared by the course author.

The completed course, as originally programmed for computer presentation, consists of the following topics (ten chapters):

- I. Introduction to management accounting:
  - A. The responsibility accounting and dual posting concepts in relation to cost accumulation for (a) control and (b) income measurement permeate the entire course.
  - B. Distinction between accounting procedures for merchandising and manufacturing firms.
- II. The cost accounting cycle (accounting for materials, labor and overhead.)
- III. Basic cost accounting systems (historical and standard costing systems):
  - A. Job order costing
  - B. Process costing
- IV. Control of manufacturing costs (classification of costs as fixed, variable and semi-variable for control purposes, and usefulness of the flexible budgeting technique for control of factory overhead costs).
- V. Accounting data for business decisions (an introduction).

In view of recent curriculum changes by the accounting department at Penn State, the course author plans to expand the above outline to include direct costing and budgeting (period planning).

Course Author, Student and Computer

The course included in the research was prepared by utilizing a special author language developed by IBM computer scientists at the T. J. Watson Research Center. The language is not bound by or committed to any particular teaching methodology.

A very limited knowledge of computers is necessary to use this language. Authors implement their own instructional techniques or teaching methods as courses are written.

With the special language the author can include questions, problems, assignments, correct answers, incorrect answers, knowledge of results, branches, or alterations in the course sequence, etc. The course is stored on a magnetic disc to which the computer has selective access to any part with a delay of time of less than one second.

The course is presented to students via an IBM 1050 teaching terminal. This terminal consists essentially of a modified electric typewriter through which the computer types out course material to a student seated at the terminal. Information can also be presented by slide projector and tape recorder under control of the computer.

In answering a question or problem, the student simply types his answer at the terminal and relays it to the central computer which in turn provides immediate feedback or knowledge of results to the student. Thus the teaching station is an input-output device. The computerized version of the course is demonstrated by the following illustration of a short sequence. In this case problem, it is assumed that the student has read the relevant section of the text or other assigned readings dealing with computation of equivalent units and unit costs.

Short Process Cost Problem

Imelda Processing Corporation incurred $40,000 of production costs during the past month. Materials costing $22,000 were introduced at the start of processing, while conversion costs of $18,000 were incurred at a uniform rate throughout the production cycle. Of the 40,000 units of product started, 38,000 were completed and 2,000 were still in process at the end of the month averaging one-half complete. No inventory was present at the beginning of the month.

REQUIRED:

1. The equivalent units of production for (a) materials, (b) unit conversion costs.
2. The cost of (a) ending work-in-process inventory, (b) goods manufactured.

The case problem can be either typed out to the student by the computer or instructions given directing the student to acquire the problem from the person in charge of the teaching station. After the student has studied the problem he signals the computer to initiate the instructional sequence which, in effect, tests or demonstrates the student's understanding of assigned reading materials.

In the following example, a section of the course based on question 1(a) of the above problem is presented and explained. Notice that both main line as well as remedial questions or instructions are labeled so that the random access feature of the system can be implemented.

la 1-1
rd In the Imelda Processing Corporation problem it is assumed that no inventory was present at the beginning of the month. Therefore, identical results are achieved irrespective of whether the average costing or first in, first out method is employed. Nevertheless, use the basic framework as set forth for average costing in order to solve the problem. Press (EOB) when you are ready to proceed.
la 1-2
qu What is the equivalent units of production for materials?
xl 90
ty Try to work faster.
ca 40,000
cb 40,000 units
ty Very good. It is apparent from your response that you understand the procedure for calculating equivalent units.
br 1-3
wa 39,000
wb 39,000 units
ty Your answer is incorrect. Read the problem again, and pay particular attention to the manner in which materials are introduced.
un Try again. Remember that materials are introduced at the *start* of processing.
un Perhaps you do not recall the definition of an equivalent unit. Remember that equivalent units must be calculated for each cost element, and you are to restate units associated with each in terms of completed units.

Explanation of la 1-1 and la 1-2: The computer presents instructions to the student in la 1-1 and he is told to signal completion after which a question (la 1-2) is typed out by the computer. The student is then given ninety seconds in which to respond. If an answer is not entered during this time period, the computer commands the student to work faster. Thus, student responses (including failure to respond) determine which operation codes will be executed by the computer. If the student responds by entering either the ca or the cb the computer will give the type out associated with the correct answer and proceed to la 1-3 which is the next main line question in the sequence. If either the wa or wb response is given by the student the computer will give the associated type out and wait for the student to try again. The course author can include as many correct and incorrect answers as he wishes. In this particular sequence the computer would give the first un if the student entered a response not programmed by the course author. If this is done

a second time the second un would be executed and the student enters a remedial branch. Assume that the student gives two unrecognized responses. The computer would then "branch" him to la 1-2a.

br	1-2a
la	1-2a
qu	The general procedure for computing equivalent units is based on the following formula: Units completed and transferred plus units included in ending work in process inventory (expressed in terms of completed units) equal total possible production. Deduct beginning inventory (expressed in terms of completed units) from total possible production in order to determine equivalent units of production for the current period. Notice that it may be necessary to make separate calculations for materials, labor, and factory overhead, depending upon whether or not these items are added at a uniform rate during the production process or at the start or end of processing, etc. Thus, you should read each problem carefully. Are you now able to determine equivalent units of production (in this case materials put into process) for materials by using the above formula? If so, type in your answer as adjusted.
ca	40,000
cb	40,000 units
br	1-3
un	This answer is also incorrect. Now consider a step-by-step solution.
br	1-2b
la	1-2b
qu	How many units were completed and transferred during the period?
ca	40,000
cb	40,000 units
br	1-3
ca	38,000
cb	38,000 units
ty	Correct. This information is given in the problem.
un	The answer is given in the problem. Type it in.
la	1-2c
qu	How many (equivalent) units of materials were included in ending work-in-process inventory?
ca	40,000
cb	40,000 units
br	1-3
ca	2,000
cb	2,000 units
ty	Very good! You apparently understand that all units are 100% complete with respect to materials since *all* materials are introduced *at the start of processing*.
un	Read the problem again in order to determine the "stage of completion" of all units with respect to materials, and try again.
un	All units are 100% complete with respect to materials. Thus equivalent units of materials included in ending work in process inventory amount to 2,000. Type in the correct answer. Take a minute to make a personal note to review the procedure for calculating equivalent units.
la	1-2d
qu	Is the following statement true or false: Beginning work in process inventory is zero. Therefore, equivalent units would be zero for the various cost elements.
ca	true
cb	True
ty	Correct. The answer is given in the problem.
wa	false
wb	False
ty	Incorrect. Type in the correct answer; it is *given* in the problem.
la	1-2e
qu	You now have all the necessary data for calculating equivalent units for materials. Type in the answer.

```
ca  40,000
cb  40,000 units
ty  Correct
la  1-3
```

```
qu  What is the equivalent units
    of production for conversion
    costs?
    etc. . . .
```

Explanation of 1a 1-2a, 1a 1-2b, 1a 1-2c, 1a 1-2d, and 1a 1-2e: *The random access branching feature of computer-assisted instruction is demonstrated by this sequence. This feature represents a significant advantage of computer-assisted instruction over other types of programmed instruction. For example, given the previous assumption that the student enters two unrecognized responses to question 1a 1-2, he is branched to 1a 1-2a (a remedial question) where a hint is given which presumably should enable him to answer the question from which he has been branched. Only if the correct answer to 1a 1-2 or 1a 1-2a is given will the student proceed to the next main line question (1a 1-3). If the hint does not enable the student to answer the question and he transmits another incorrect answer, he is branched to remedial question 1-2b. In order not to penalize the student who can answer the main line question by forcing him through the entire remedial instruction sequence the student is given a chance of answering either the main line question from which he has been branched or the remedial question. If he does the former he is branched to the next main line question in the sequence, whereas, if he takes the latter route he is given the next remedial question leading up to an accumulation of sufficient information which will enable him to answer the question from which he has been branched. Thus, a student who has a thorough understanding of his assignment is able to work through a sequence which would include fewer questions than the student who experiences difficulty. Irrespective of the actual path taken by each student, immediate feedback is provided by the computer so that he "knows where he stands."*

In the actual program the short problem above is expanded to include beginning inventories, both first in, first out and average cost calculations, spoilage calculations, more than one producing department, etc., which enables the student to acquire thorough exposure to relevant procedural aspects of process costing.

As illustrated, the branching technique permits the computer to alter the sequence of presenting course materials based on responses of each student, thereby recognizing individual differences. Another advantage is that the student cannot see the information stored in the computer. Unless the author includes "help" sequences in the program, the student must rely on what he has learned. Each student will get different responses from the computer based on his answers to questions, etc.

The course author attempts to develop the program in a flexible manner to facilitate the learning process of as many students as possible. In addition to the above described branching technique, it is now possible to incorporate a conditional branching feature whereby a student is automatically branched if his (accumulated) error rate exceeds a certain predetermined percentage.

The special author language includes many other functions and operation codes—including tape recorder and slide projector controlled by the computer—which facilitate the learning process. Space does not permit a detailed discussion of these items.

Student Reactions

The following comments are based on observations during the fall term of 1964.

Fifteen students who were concurrently enrolled in the ten-week course for college credit volunteered to serve as subjects during the fall term. Portions of five chapters of the program were tested.

Student subjects indicated that they were initially fascinated by computer-assisted instruction and impressed by the large degree of student independence which characterizes the learning situation as well as the ability to proceed at their own pace. Three students informed the course author that for the first time during college that they were able to direct meaningful question to the instructor, graduate assistant, or in class, as a result of reviewing computer accumulation of student records which are available to both student and course author.

In addition, student subjects expressed great satisfaction for having been given an opportunity to participate in a research project with their classroom instructor. This type of student-teacher association (at the larger university) is usually restricted to the graduate student.

Interestingly enough, the majority of student subjects indicated that the early developmental stage of computer-assisted instruction has permitted a greater degree of student-teacher interaction, especially on the large college campus. Future implications of this aspect of computer-assisted instruction is, of course, a separate problem.

Several students became "bored" after having worked at the computer for a few sessions. Discussions with these students revealed the following reasons for this situation: Inability to proceed at the same pace as formal classroom assignments due to constraints on computer time and facilities, and necessity to, in effect, prepare "two" assignments—one for actual course credit and the other for the research project. Demands on student subjects' time in view of enrollment in other courses thus accounts for part of this reaction.

Some students were nervous because of exposure to a new teaching medium or inability to type as proficiently as they would have liked, coupled with the mere idea of having to "operate a machine." Most students subsequently adjusted to computer-assisted instruction if they were permitted to work alone and if someone was available in case of "difficulty" with hardware and course content.

Review of student records also revealed that there was a noticeable increase in the amount of material covered (number of lines) as the student progressed through the program, and that there was no apparent reduction in errors traceable to the student and those traceable to the hardware.

Errors traceable to the student relate to general misunderstanding of accounting concepts and procedures previously covered in prerequisite accounting courses, interpretation of questions, spelling and grammar, arithmetic errors, and exposure to new accounting concepts and procedures not readily comprehended for the first time.

Errors traceable to the hardware (as well as the course author) relate to the rigid manner in which student responses are matched with those included in the computer program, failure to anticipate and program acceptable answers transmitted by student (due to terminology, etc.), and other general errors in programming.

In addition, students commented on frustrations resulting from having to "wait" at the terminal for data to be transmitted by the computer.

Most of the above student reactions can be explained by the fact that computer-assisted instruction is going through the initial research stages. During recent months rapid strides have been made in improving the special author language so that much more flexibility is given the computer in recognizing alternative student responses and providing sufficient hints which will reduce student frustrations in the future.

Experience of the Course Author

Computer-assisted instruction is a relatively new area of research. Consequently, course authors and graduate assistants were also subject to an "adjustment process" and they experienced frustrations similar to those of student subjects. Early experiences of the author in developing materials for the management accounting course are indicated in the following three comments.

Original plan to develop course from classroom text materials. Even though a text is required for students, in the usual classroom situation all students are exposed to a broader coverage of the subject matter. Hence, rigid reliance on text materials alone would limit severely the teaching effectiveness of a computer program.

Course authors can overcome the above strait jacket by either preparing supplementary reading assignments for student subjects or requiring library reading assignments.

To serve the needs of a wide student and instructor audience and derive benefits from a computerized course commensurate with costs associated with its preparation, "canned" programs will have to be written in a flexible fashion such that pedagogy peculiar to individual professors can be reflected therein with a minimum amount of revision. Computer scientists have already developed methods of storing course materials which will permit such flexibility. In other words, a well-written course can be modified simply by inserting or deleting sections based on the discretion of the in-charge or supervising professor. Not only can pedagogical differences be recognized in this manner, but costs associated with continuous updating and necessary revisions of course materials can be held to a minimum.

Revision of course materials. The necessity for revising sections of the course implied by the preceding discussion also results primarily from improvements in the special author language and review of records of student errors accumulated by the computer.

In view of substantial improvement and expansion of the author language since initiation of the research project, future revisions of the course materials will incorporate some of the more recently perfected operation codes where applicable. The completed version of the course will also include quizzes, examinations and additional case problems.

Student records provide indispensable information for revising flow charting and block diagramming of course materials so as to improve the interrelationships between course materials, computer and students. Obviously, the task of revising course materials from this type of information is a continuous one. These revisions will enable the course author to develop materials with sufficient generality and flexibility to fit individual requirements of students.

Teaching of concepts and practical applications. An important implication of the use of computer-assisted instruction, as revealed by preliminary testing of the management accounting course by student subjects, is that the use of this form of instruction is relatively more effective for the purpose of teaching procedural aspects and practical applications (approaches to solving problems, etc.) as compared with the teaching of concepts and theoretical considerations. For example, computer-assisted instruction is not presently developed to the stage whereby the equipment can handle and process complex essay questions and discussions of concepts in a manner to reflect individual differences of students. Distribution of supplementary reading assignments, referred to earlier, is the method used in the management accounting course to overcome this possible shortcoming of automated teaching. On the other hand, computer scientists continue the search for methods of improving the hardware so that complex and complicated student answers can be processed.

Concluding Observations

The future of computer-assisted instruction will, no doubt, be viewed with great optimism and eager anticipation due to the present education explosion and shortage of faculty as well as the limited funds available to accommodate the required expansion in educational activities. As indicated by its name, computer-assisted instruction is intended as an *assisting* device.

As is generally true with the introduction of any form of change, observers are concerned and will continue to be concerned with many questions relating to the future prospects of computer-assisted instruction. For example, cost-benefit and other feasibility studies will be undertaken and reactions of and effects of this new form of instruction on students will be analyzed. No doubt, computer-assisted instruction, even in its development stages, has one compelling positive slant: *all* teaching simply cannot be done by human beings!

Appendix H.2

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Computer-assisted instruction: implications for teacher education

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There is agreement between mathematicians and educators that future and in-service teachers need a good background in mathematics subject matter. Toward this end many colleges, universities, and school systems have developed content courses for elementary teachers that are very similar to the recommendations of the Committee on Undergraduate Program in Mathematics of the Mathematical Association of America.

With the increased press of enrollments in these preservice and in-service courses, it has become increasingly difficult to find instructors who can teach these content courses in a manner that not only improves the student's background but also improves the student's attitude toward mathematics. In this article the authors will explore the possibilities of the use of computer-assisted instruction in mathematics courses for elementary school teachers and will report findings from a field trial in which CAI was used as the major portion of a college mathematics course. To the best of the authors' knowledge, this is the first attempt at such a use of CAI.

Just what is CAI? The name should convey the concept of a computer's being used as an aid in the teaching-learning process. Essentially, it is programmed instruction presented under computer control. Course content is programmed using Coursewriter, a computer language developed by International Business Machines Corporation's Thomas J. Watson Research Center. The program is stored and relayed by a computer, in this case an IBM 1410 data-processing system located at the Computation Center, The Pennsylvania State University. Course materials are processed over telephone lines for presentation on IBM 1050 student terminals—a modified electric typewriter, random-access slide projector, and tape recorder unit.

Each student relays his response to the computer, which evaluates the response, provides knowledge of results if correct, and then either shows a slide, plays a tape, or types out the next question. If the answer is an anticipated wrong answer, a specific clue is provided; and the student again responds to the question. For unanticipated wrong answers, the computer either types out a series of clues or the reason for the correct answer, or branches to a series of small-step questions. Coursewriter allows for partial answer-processing on such factors as key words or spelling. Branching decisions are based on particular answers, on an accumulated error count, or on student decision.

There are several advantages that have been noted for CAI, particularly in comparison with other programmed devices:[1]

1. The computer carefully controls the learning sequence of each student and requires the student to comprehend each frame.
2. The computer can judge constructed responses for accuracy.
3. The computer may offer a more stimulating learning situation than is sometimes provided by programmed texts.
4. The computer can utilize background information on each student for constructing learning sequences and judging responses.
5. The computer is more versatile than the programmed text. It can teach a wider variety of tasks and employ a wider range of auxiliary stimulus-presentation equipment.
6. Currently, there is a great deal of interest in the use of a guided discovery approach to the teaching of mathematics. The author of a CAI sequence is able to use the same type of guided questioning that is typical of guided discovery patterns. In fact, it has an advantage over a guided discovery discussion, since each learner must respond to each question, experiencing discovery himself.
7. The computer offers data on the entire learning session as well as summary information. These data can be useful in revision of a programmed sequence as well as for school records and research purposes. Students can use their "type-outs" for study. Also, student records can be very useful in analyzing the thinking patterns of students.
8. The computer is a long-term investment that may be used for a variety of purposes, such as data processing. It may be less expensive and less space-consuming than programmed texts.

Is CAI an effective means of teaching? This is a question that needs thorough study. The field test report that follows is a small piece of the evidence necessary for adoption of CAI procedures on a wider scale.

The course used in this study was programmed on the basic mathematics content of Math 200, for freshmen and sophomores in the elementary-education sequence at PSU.[2] In addition to the course text,[3] other references were used as content guides in writing the program.[4] The material was divided into fourteen chapters, with the following indicative titles: Sets; Relations; Exponents; Our Numeration System; Other Numeration Systems; Whole Numbers: Addition, Subtraction, Multiplication, Division; Integers; Rational Numbers: Fractions, Decimals, Ratio and Per Cent; and Real Numbers.

The strategy of instruction for the CAI *mavmath* program[5] uses several basic assumptions concerning the teaching-learning process.[6] These are:

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[1] Many of these were adapted from Walter Dick, "The Development and Current Status of Computer-Based Instruction," *American Educational Research Journal*, II (January 1966), 41–54.

[2] This course was developed as a portion of "The Development and Presentation of Four Different College Courses by Computer Teleprocessing," a research project funded under the provisions of Part B, Title VII of the National Defense Education Act of 1958, U.S. Office of Education Project Number OE-16-010, College of Education, The Pennsylvania State University.

[3] John A. Peterson and Joseph Hashisaki, *Theory of Arithmetic* (New York: John A. Wiley & Sons, 1963).

[4] Francis J. Mueller, *Arithmetic—Its Structure and Concepts* (Englewood Cliffs, N. J.: Prentice-Hall, 1964).

Robert L. Swain and Eugene D. Nichols, *Understanding Arithmetic* (New York: Holt, Rinehart and Winston, 1965).

M. Ward and C. E. Hardgrove, *Modern Elementary Mathematics* (Reading, Mass.: Addison-Wesley Publishing Co., 1963).

G. Cuthbert Webber and John A. Brown, *Basic Concepts of Mathematics* (Reading, Mass.: Addison-Wesley Publishing Co., 1963).

[5] The title *mavmath* is formed from "modern mathematics with audiovisual aids"; tapes and slides are activated by the computer. Another version, *madmath*, uses a book of displays in place of the tapes and slides.

1. Mathematics is best learned when students are encouraged to discover the basic ideas, laws, or principles of mathematics. Thus, students should be given a chance to solve a new problem rather than be shown how to solve it first.

2. The reason for studying a topic should be made clear by the manner in which it is introduced.

3. "Individuals differ in their receptivity for learning."[7]

4. "Effective learning is continuous and developmental in nature;"[8] thus previous generalizations and facts are helpful in developing new generalizations.

5. "Continual failure by an individual at any level makes for ineffective learning."[9]

6. "Active participation by the student tends to produce an effective learning experience."[10]

7. "Knowledge of one's progress contributes to effective learning."[11]

A belief in these assumptions leads to a teaching procedure in which the student is presented with a problem that can be solved by his use of previous knowledge and his thoughtful discovery of the next step of knowledge in the subject. This approach can be called an *inductive* approach. A *deductive* approach is usually used in programmed materials. The following contrasts these two approaches:

Inductive Approach

Student is presented with problem.

If problem is solved by student, he is led to refine his procedure for solving problems of this type.

Student is asked to develop a generalization.

If student cannot solve problem, he is asked developmental questions which lead to the solution.

Student solves a similar problem.

Deductive Approach

Student is presented with generalization.

Student is presented with illustrative problems in which the process of solution is explained.

Student applies the generalization to solving problems.

The *mavmath* program attempts to make use of a teaching technique similar to the inductive pattern. One or two questions cannot adequately convey this pattern; however, the following sequence from the program is included to illustrate the way in which the material is programmed for the computer. The flow chart (next page) depicts the questions and comments in graphic form, so that the procedure used by the computer may be better visualized.

There are approximately one thousand questions, which every student answered. There are also branching questions; the number of these answered by each student varied. The study did not attempt to control the number of questions or time.

The problem that was explored referred to the value of CAI—how does it affect the achievement of a group compared with the achievement of a group in the traditional class pattern?

The population—all freshman students in the elementary education and special education curricula at PSU who were scheduled for Math 200 during the spring term of 1966—were assigned to sections, at random, by a computer. From the four sections, one was selected at random. The 26 students in the section (all women) were pretested with a 40-item test of mathematical content developed by the authors (Kuder-Richardson, Formula 20, $r = .82$); the results were used as a basis for selecting ten matched pairs of students. One member of each pair was randomly assigned to the CAI-treatment group and one to the teacher-treatment group.

All students in the section met together for one standard 75-minute period per

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[6] Francis G. Lankford, Jr., "Implications of the Psychology of Learning for the Teaching of Mathematics," *The Growth of Mathematical Ideas, Grades K-12* (Washington, D.C.: National Council of Teachers of Mathematics, 1959), pp. 405-40, contains a more extensive list of learning principles for teaching mathematics.

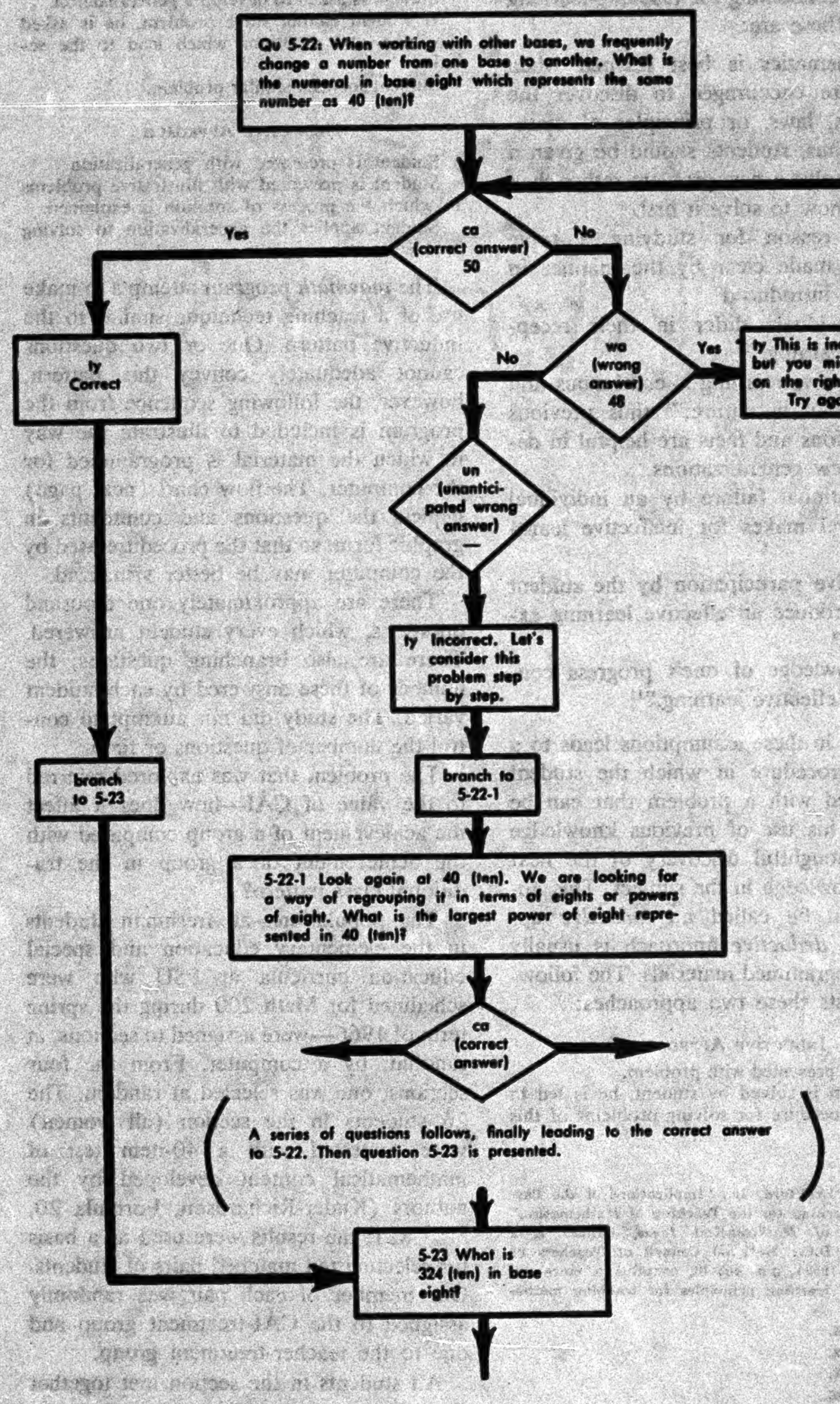
[7] *Ibid.*, p. 412.

[8] *Ibid.*, p. 419.

[9] *Ibid.*, p. 422.

[10] *Ibid.*, p. 426.

[11] *Ibid.*, p. 428.


Qu 5-22: When working with other bases, we frequently change a number from one base to another. What is the numeral in base eight which represents the same number as 40 (ten)?
ca (correct answer) 50
Yes
No
ty Correct
wa (wrong answer) 48
Yes
No
ty This is incorrect, but you might be on the right track. Try again.
un (unanticipated wrong answer) —
ty Incorrect. Let's consider this problem step by step.
branch to 5-23
branch to 5-22-1
5-22-1 Look again at 40 (ten). We are looking for a way of regrouping it in terms of eights or powers of eight. What is the largest power of eight represented in 40 (ten)?
ca (correct answer)
A series of questions follows, finally leading to the correct answer to 5-22. Then question 5-23 is presented.
5-23 What is 324 (ten) in base eight?

week for discussion that centered on their questions in regard to content. Both groups used the text *Theory of Arithmetic,* by Peterson and Hashisaki, and both were provided with the same study guides. The instructor of the course was coauthor of the CAI program, and he used the same outline for the class as had been used in developing the CAI program. Both groups were considering the same topics each week. As a measure of control on outside-of-class practice, the answers to study guides were collected.

The teacher-treatment group met twice a week for class periods of 75 minutes each. The instructor developed the mathematical content inductively, to parallel the premises of the CAI program. The CAI-treatment was scheduled for 2½ hours per week on the computer, equivalent to the time spent by the teacher-treatment group. Instruction and testing occurred within a standard ten-week term.

The posttest was developed from a specially written 200-item pool prepared by the authors. Items were selected from the pool on the basis of balance of content, content validity of the item, and indices of difficulty and discrimination. The test items are divided into three classifications: knowledge (30 percent), understanding (32 percent), and application (38 percent). A reliability of .82 (Kuder-Richardson, Formula 20) was found for the 50-item posttest.

The mean of the teacher-treatment group on the posttest was 40.9, while the mean for the CAI-treatment group was 40.4. By inspection, the difference between the means does not appear to be statistically significant. For the sake of precision, a t-test was performed; a t of .07 resulted. The null hypothesis that the two groups are equal cannot be rejected.

What implications for the use of CAI does a finding of "no significant differences" have? In this study, CAI students fared as well as students in an unusually small class. Thus CAI appears to be a feasible tool for teaching mathematics courses for preservice teachers.

There are several other facets of elementary-teacher education in which CAI should receive more than cursory examination:

First, CAI could be used as a short course for the preservice teacher with an extremely good background. This would allow that student to learn more mathematics in the time allowed for the study of mathematics.

Second, CAI has great potential for in-service work. At present, the typical pattern of in-service education involves after-school or evening meetings with an instructor from a nearby college, a faculty member from the senior high mathematics department, or a fellow teacher or administrator who has attended an NSF summer institute or a comparable program.

Several difficulties arise from this type of program.

There is the passiveness of the situation. The teacher sits and listens rather than actively working on the material. Using CAI, the teacher would be actively involved in learning the content. One doesn't just sit and allow an electric typewriter to hum.

Teachers would not have the resentment they sometimes feel when a secondary school or college "expert" or a fellow teacher tells them what to do. CAI content-instruction would allow the educational leader in mathematics to take the lead in discussion centered on the implementation of good mathematics programs.

Third, CAI is a good device for studying sequencing of mathematical materials and teaching methods. It allows for control of the teacher factor in research studies of the type that ask such questions as, "Should multiplication and division be introduced on the same day?"

Up to now, a rather positive view of CAI has been presented. However, there are some questions to be answered concerning the use of CAI:

1. Few students have had more than one course offered by this method; what is the reaction to long-term study by CAI?

2. At the present time, there are the technical difficulties associated with any new product—can they be solved? Just as the television set of 1950 needed repairs every few months, the present CAI systems have sometimes frequent disruptions. These problems hopefully will be overcome with increased experience and use.

3. Writing CAI materials takes a long time. The authors spent the equivalent of two man-years on a course that is approximately a two semester-hour college course. Ways of improving writing speed without hurting quality must be explored. Thus the question, "Can programs be developed more efficiently?" needs to be answered.

4. At the present time CAI is expensive, as are most newly developed devices. What will be the cost of widespread use of CAI? Only time will tell. However, some experts contend that the cost will be reduced to one dollar per hour on the terminal.

5. The computer may be psychologically threatening to some students. The persistent questioning is demanding. Can this threat be overcome? Should all students take CAI courses? Are there requirements for adapting to learning by CAI?

Will CAI be a standard classroom feature in the future? If the current interest and development is any indication, the answer is yes. However, it is hoped that educators will begin to learn something from the history of other new media. In particular, it must be realized that an innovation such as CAI can be neither better nor worse than the scholarship and creativity of the persons developing the program allow. If CAI courses are carefully developed, the authors feel, CAI offers greater potential than previous innovations such as sound film, television, radio, filmstrips, and conventional programmed instruction. While the jury is still out, CAI offers one of the most exciting methods of studying the teaching-learning process.

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Educational requirements for a student-subject matter interface

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INTRODUCTION

The problem of communicating knowledge, skills, and attitudes to students has concerned educators for centuries. Earlier debates centered around the use of lecture versus discussion methods, the use of the textbook, workbooks, etc. In general, these earlier "media" of instruction were passive display devices requiring relatively little response involvement on the part of the learner. Recent advances in communications technology have revived interest in the question of the media of instruction and have broadened the avenues through which the learner may come into contact with his subject. In general, the newer instructional display and response devices are "active" as opposed to earlier more passive media. They provide for the adaptation of the instructional materials to the characteristics of the individual learner as contrasted with earlier "static" display devices, and require active response involvement by the learner in the process of instruction. These devices allow the learner to *interact* overtly with his subject.

Paralleling the recent technological developments in the area of computers and communications systems, there has been an emerging technology of learning and instruction. A new breed of educational psychologist has emerged which is dedicated to the proposition that education can and should be a science and not an art. Armed with the tools of behaviorism and operationalism, he critically analyzes complex subject matters, behaviorally defines and evaluates instructional objectives, systematically arranges instructional experiences to optimize learning, and applies theoretical models to the process of instruction. It is not surprising that these investigators should also address themselves to the problem of the optimization of the modes of communication used in instruction.

In computer-assisted instruction (CAI) the term "student-subject matter interface" describes the devices such as two-way typewriter, cathode ray tube, slide projector, tape recorder, etc., through which the student interacts with the subject matter. The two major dimensions of the interface are its stimulus display capabilities and its response processing capabilities.* Stimulus display capability refers to the varieties of ways that a subject matter can be displayed to a learner through the interface. Response processing refers to the variety of student responses which can be detected by the interface and processed by a computer. The present paper will examine several classes of educational variables which determine the characteristics of an effective interface. The four categories of educational variables which must be considered in the design of the interface are the characteristics of the subject matter, the characteristics of the learner, the nature of the instructional process, and the objectives of instruction.

Subject matter characteristics

Perhaps one of the more obvious factors affecting the capabilities which must be available in an interface is the subject to be taught. Different subjects require different interface characteristics. The most extensive study of the relationships between subject matter characteristics and interface requirements has been made by Glaser, Ramage, and Lipson.[1] These investigators conducted an extensive analysis of the behaviors involved in learning three subjects: elementary mathematics, elementary reading, and elementary science. The analysis was based on an actual survey of instructional programs and curricula used in the schools. From this task analysis Glaser and his associates were able to draw up a set of specifications for an instructional environment to teach each of the subjects. A summary of their findings is shown in Table 1. The table shows the wide variety of interface requirements for elementary mathematics, reading, and science subjects. Science appears to provide the greatest challenge to the development of an instructional environment. For example, science instruction often requires the visual display of natural phenomena and simulation pictures. One can't help but note the obvious advantages of a closed circuit television capability as part of the interface for displaying scientific phenomena. Science instruction also appears to place rather sizable demands on the interface in the area of response processing, thus, there are times when the learner may need to manipulate controls, construct graphs and figures, etc.

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*The stimulus display and response processing capabilities of a CAI system are not solely dependent on the interface device. These capabilities are usually a joint function of both the interface, the computer, and the software. The lack of an important display or response processing feature may be due to a limitation in the interface device, the computer, the software, or some combination of several of these factors. Regardless of the source of the deficiency the net effect on students is the same. The lack of an audio capability may be just as serious whether it results from an inadequate recording and playback system, a limitation of the central computer, or a lack of available software. The purpose of this paper is not to analyze how the various display and response processing capabilities may be implemented technologically. This would be a task for the engineer and computer scientist. The present paper will be concerned with the educational variables which must be considered in establishing specifications for a student-subject matter interface.

Some of the requirements listed in Table I are easier to implement than others. For example, our experience at the Penn State CAI Laboratory indicates that it is a relatively simple matter to provide various types of manipulanda for the student at the

Table I

Stimulus and Response Requirements for the Instructional Environment in Elementary Mathematics, Reading, and Science

	MATHEMATICS	READING	SCIENCE
Visual Stimulus	*Numerals *Symbols *Drawings *Pictures *Words *Objects *Meaningful arrays	*Pictures *Symbols *Letters *Words	*Natural phenomena *Pictures and drawings *Simuluation pictures
Auditory Stimulus	*Sound patterns *Words (for young students)	*Words *Sounds for symbols	*Sound phenomena
Tactile Stimulus	Objects for manipulation	Letters (for young students	Natural phenomena-friction, heat, textures, etc.
Visual Display for Response	*Numeral *Figures *Symbols *Objects *Letters and words *Sequential choice display	*Letters *Pictures *Words	Manipulative controls *Sequential choice display
Auditory Response Detection	Words (for young students)	Phonemes Words Names of letters Words in context	Words (for young students)
Object Display and Manipulation	Numbers of objects Patterns of objects	Letters as objects (for young students)	Models and objects of science area
Symbol and Figure Construction	Geometric figures		*Graph construction *Figure construction
Sequential Stimuli	*Algorithm problems	*Reading in context	*Cycles *Natural sequences *Laboratory sequences
Time Factor Presentation	*Patterns in time	*Introduction of prompts with delayed response	*Time factor in natural phenomena

From Glaser, R., Ramage, W. W., and Lipson, J. I. *The Interface Between Student and Subject Matter.* Learning Research and Development Center, University of Pittsburg, Pittsburgh, Pa., 1964. pp. 177.

*Instructional functions which probably can be implemented in a CAI system within the foreseeable future.

instructional terminal. One course in audiology covering the anatomy of the ear provides the student with various plastic models of the ear and the skull. The student is taught to identify the anatomical parts of the ear both by reference to slides depicting the various parts of the auditory system and the actual models.

One conclusion seems evident from an examination of Table I. Existing interface capabilities cannot accommodate all of the requirements of these subject matters as they are presently taught in the schools. Furthermore, it is doubtful whether some of these capabilities (voice detection for example) will be feasible in the very near future. This observation is not surprising in view of the fact that most classroom instruction provides a wide variety of experiences for the learner. It must be remembered that Glaser's analysis represents the total spectrum of instructional experiences and few investigators expect CAI to reproduce all aspects of these experiences. The rather marked discrepancies between the requirements of Table I, and current interface capabilities reemphasizes the widely held view that CAI must be *supplementary* to existing instructional techniques. Mitzel[2] has pointed out that one of the most important problems to be solved in the development of CAI is the determination of the appropriate "mix" between computer-mediated instruction and components of instruction which are mediated by the teacher or by still other means such as educational television. It is likely that the nature of the "mix" will be determined in part by the kinds of instructional experiences which can be efficiently and effectively provided by the CAI interface. Those experiences which cannot be implemented via CAI must be provided by the teacher or by some other means.

What are the instructional functions which can feasibly be provided within the next generation of CAI systems? I have indicated my own conjectures with regard to this question by marking with an asterisk those instructional functions listed in Table I which I think can be implemented within a CAI system in the foreseeable future.

Work with high school and college level CAI courses at Penn State (Mitzel,[3] Mitzel and Brandon [4,5,6]) indicates that the level of the subject matter is also a critical variable in determining the requirements of the interface. Elementary mathematics presents one set of interface problems and higher mathematics another.

The nature of responses in a mathematics program are often such that the course author is willing to accept as correct a range of answers. In the course of solving a complex mathematics problem rounding errors may result in minor variations in the numerical answer. If the computer is programmed to require a perfect match of the student's answer with a prestored answer, answers which are essentially correct will be regarded as incorrect by the machine. As a solution to this problem, IBM[7] has developed a "limit function" as part of their *Coursewriter* language. Limit function allows an author to program the computer to accept all responses within certain specified limits as correct responses.

Another problem occurs in attempting to teach college mathematics using a typewriter terminal to display the course and process student responses. Mathematics frequently involves the display of relatively complex equations and symbolic configurations containing subscripts and superscripts. The typewriter is not efficient in dealing with such materials, and may actually interfere with learning when the student is confronted with the complex task of inputting symbolic material. The cathode ray tube display may alleviate this problem to some extent, but the problem of inputting symbolic material through a keyboard still remains. It is noteworthy that even the most experienced typists have difficulty in reproducing material containing many symbols and equations. IBM attempted to solve this problem by developing a mathematics typehead and a keyboard mask to aid the student in identifying the new character set. Our experience with this device at Penn State suggests that it is satisfactory for relatively short responses, but that it does not greatly simplify the inputting task for longer symbolic responses. IBM's discontinuation of the mathematics typehead for its 1050 communications system suggests that they may have had similar misgivings concerning this procedure.

Mathematics is not the only subject matter which presents special problems for the CAI interface. Several studies conducted at Penn State (Wodtke and Gilman,[8] Wodtke, Gilman, and Logan[9]), demonstrate that the typewriter is an inefficient interface for highly verbal subjects at the college level. When identical instructional programs were administered on-terminal and off-terminal there was an increase in instructional time of 25 per cent in the on-terminal group with no commensurate increase in learning. In a second study employing a still more highly verbal program, the increase in instructional time was 75 per cent for the on-terminal group with no significant difference in learning when compared to the off-terminal group. The largest portion of this time decrement is undoubtedly due to the slow type-out rate of the typewriter (approximately 120 words per minute) which is substantially slower than the normal reading speed of the typical high school or college student.

In an area of research where variations in instruction typically produce only small gains in student achievement, a time loss of 25 per cent represents a substantial decrement. The time could be used to give students more practice, instruction on new material, or practice on transfer problems. In addition to the gains in student learning which might accrue from a more efficient use of instructional time, there are also economic considerations in the cost of computer time, tie-lines, and other "hidden" costs involved in the preparation of courses. All other things being equal, by employing an interface which would decrease instructional time by 25 per cent without reducing the amount learned, four students could be taught for every three taught by means of a typewriter interface.

From the college student's point of view, learning at a typewriter terminal is not self-paced instruction since he must slow down his normal rate of work. Pacing instruction below a student's optimal rate could produce boredom, negativism, and avoidance of CAI as an aid to learning. This is not an uncommon finding when the pace of classroom instruction by the lecture method is too slow for the brighter students. The advent of the cathode ray tube display device should speed up substantially the display of verbal information to students.

The results obtained with the typewriter interface at Penn State are not consistent with the results reported in several other studies. Grubb and Selfridge[10] compared the performance of college students taught descriptive statistics via CAI, conventional lectures, and programmed text. Those students taught via CAI took one-tenth as long and achieved twice as well on the final posttest as did the other two groups! These results are so spectacular that they demand replication by other investigators. Schurdak[11] found that students who learned Fortran programming via CAI saved 10 per cent in instructional time, and performed 10 per cent better than students using a standard text or a programmed text. These somewhat more modest results conform more to expectations than the phenomenal results reported by Grubb and Selfridge.

The nature of the subject matter is also an important determiner of the response processing requirements of an interface device. Relatively simple drill programs may not require very extensive response processing since most student responses are of the short answer variety. College-level tutorial and problem-simulation programs will ordinarily require a CAI system with partial-answer processing capability. Partial answer processing refers to the capability of the computer to search a student's response for the essential elements of the correct answer; to disregard minor character mismatches, spelling, and typing errors, to regard or disregard word order in a student's response depending on the nature of the problem; etc. In one preliminary study, Wodtke[12] examined the relationship between student performance in a CAI mathematics course, and the number of times a student entered a correct answer at the terminal which was regarded as incorrect by the computer because of a minor character mismatch. The correlation between student achievement in the course, and the number of mismatched correct answers was—.80! Thus, it is quite clear that inadequacies in the computer's ability to detect correct answers seriously interferes with student learning. It should be noted that detection of correct responses is not solely an interface problem, but is also a software problem. The partial answer processing capability in the IBM CAI system is provided in the *Coursewriter* author language.

Learner characteristics

The second class of variables which must be considered in the design of an effective student-subject matter interface are individual differences among the students. The effects of some individual difference variables on the interface are obvious, for example, different interface capabilities are required for young children as compared to college students or adults. Whereas auditory stimulus display capability may be "supplementary" at the adult level, it is absolutely essential in instruction with very young children who are still nonreaders. Auditory communication would be the primary means of communication with nonreading youngsters. Glaser, Ramage, and Lipson[1] point out that auditory response *detection* would also be an essential requirement for an interface in teaching young students some aspects of mathematics, reading, and science. For example, in reviewing an elementary reading curriculum, Glaser and his associates point out that the student must acquire the following competencies involving an oral response: (1) In learning sound-symbol correspondence, the student is asked to pronounce the sounds of individual letters when written on the board or to circle or write the appropriate letter when its sound is presented, and (2) At all stages the student is asked to read aloud stories using the words he has learned. It is probable that some instructional functions such as oral reading which require oral response detection will have to be delegated to the teacher, with CAI incorporating those functions which are feasible within the present technology.

Object manipulation is likely to be another important instructional experience for very young pupils, and for older students in some subject matters such as science. According to Piaget's[13] stage theory of human development, children pass through several stages of development. Early developmental stages are characterized by sensorimotor development and the manipulation of concrete objects. Later stages are characterized by the ability to operate in more abstract terms. According to this view, the manipulation of concrete objects would be an indispensable part of instruction for elementary school children.

Although there may be mechanical methods for providing experience in the manipulation of concrete objects (Glaser, Ramage, and Lipson[1] have described an electronic manipulation board which would be capable of detecting the identity and placement of objects located on its surface), within the present stage of technology, it would seem more efficient to delegate this function to the teacher.

The CAI interface must provide a maximum of flexibility in adapting display and response modes to differences in student aptitude and past achievement. An author should have the capability of speeding up or slowing down the flow of information to a student depending on the student's aptitude or progress through the course. The variation in the rate of presentation of instruction requires a time-out feature (now available on most CAI systems) which enables the author to regain control of the terminal in the case of a student whose response latencies are excessively long. Without this terminal control, it is difficult for an author working through his computer program to alter the pace of instruction.

The need for the interface to provide graphics and auditory display capabilities also depends on the past experiences and backgrounds of the students. The typical college undergraduate has high verbal ability. CAI for college students can rely heavily on communication by means of verbal material displayed via a typewriter or cathode ray tube. However, if one considers instruction for culturally disadvantaged students or students in vocational and technical education programs, much more reliance must be placed on relatively nonverbal media of instruction. Such students will probably require more graphic displays in the form of pictures, diagrams, and drawings depicting the concepts of the course. These students may have difficulty thinking in abstract verbal terms and may require much more actual manipulation of the objects of instruction. In addition, the relatively nonverbal student might show considerable improvement in learning when verbal instruction is supplemented with auditory communication. The problem of how to communicate concepts to learners who are handicapped in verbal communication skills is an important problem for research with direct implications for the design of CAI display devices.

One learner characteristic which has important implications for the determination of the appropriate "mix" between computer-mediated and teacher-mediated instruction is the student's need for affection, nurturance, and personal contact with a teacher. This variable would be particularly important during the early stages of learning with young children. It is well known that children vary considerably in their need for affection and contact with a teacher. The need seems to be particularly acute in less mature youngsters when they are initially confronted with the complexities of a difficult learning task. Increased teacher support and nurturance may be required during the early stages of the development of a complex skill such as learning to read. Children should be tested prior to instruction so that some decision can be made concerning their need for support and contact with a teacher. The instructional system must then provide the additional personal contact required by a given child.

The branching and decision-making capabilities of the computer are the most unique and potentially important characteristics of a CAI system. To the writer's knowledge, all current CAI systems provide the ability to store information concerning the student's learning history, and the ability to make decisions to branch the student to instructional material which is appropriately suited to the particular learning history. The decision-making capability of most CAI systems is one technological capability which far exceeds our present knowledge of the process of learning and instruction. Unfortunately, psychologists are hard put to know which characteristics of the learner (immediate response history, pattern of aptitudes, response latencies, etc.) are optimum for branching decisions, and until we discover the instructional experiences which are optimal for a student with a particular learning history, the full power of CAI for individualizing instruction will not be realized.

Characteristics of the instructional process

The nature of the instructional process must also be considered in the design of a student-subject matter interface. It will not be possible in the present paper to consider all of the instructional variables which may effect the efficiency of an interface; however, some of the variables which may have special relevance to interface design will be considered.

It is a commonly accepted principle in all theories of learning, that there must be contiguity of stimulus and response for learning to occur. In common parlance, the principle of contiguity simply means that in order for a response to become associated with a stimulus, the response must occur either implicitly or explicitly in the presence of the stimulus. If a student is to learn the English equivalent of a German word, he must reproduce the English word (explicitly or implicitly) while *attending* to the German word. Hence, attention to the stimulus word or instructional display is a critical factor in instruction. It is therefore important to determine the characteristics of displays which produce a high degree of attention on the part of students. Perhaps the most relevant research on this question has been conducted by Berlyne.[14] Berlyne found that attention to a stimulus is heightened by the element of surprise, change, or novelty of the stimulus. When the same stimuli are presented in the same format over repeated presentations, attention to the task wanes, and motivation declines. The effects of novelty on behavior can be observed in any student working at a CAI terminal for the first time. The novelty of working with a machine which "talks back" has high attention holding value, at least during the early stages of instruction. The interface must be capable of providing enough variety of stimulation and novelty to sustain attention over an extended period of time. An interface which because of limited display and response processing capability provides for only very simple display and short answer response formats such as the multiple choice frame will soon lose interest for the learner.

Travers[15] and his colleagues have recently conducted an extensive review and research on various aspects of audiovisual information transmission. Travers' studies and those of Glaser, Ramage and Lipson[1] must be considered among the primary references in the field of interface design. Travers has re-examined the traditional view that the primary advantage of audiovisual presentations is in the realism they provide. Contrary to this traditional view Travers argues that increased realism may actually interfere with learning by providing too many irrelevant cues, thus, a simple line drawing may be more effective in communicating essential concepts to learners than a more realistic picture. Travers concludes:

> *First, the evidence points to the conclusion that simplification results in improved learning. This seems to be generally true regardless of the nature of the presentation – whether it is pictorial or verbal. This raises interesting problems, for the simplification of audiovisual materials is that they provide a degree of pictorial content will generally result in a less realistic presentation than a presentation which is close to the life situation. The argument which is commonly given in favor of realism which other procedures do not. The realism provided may not be entirely an advantage and may interfere with the transmittal of information. The problem of simplifying realistic situations so that the situations retain information essential for permitting the learner to respond effectively at some later time to other realistic situations, is an important one!*[15] *(pp.2.110-2.111).*

The limited capacity of a cathode ray tube for displaying a high degree of realism may not be such a deficiency after all.

A more recent experiment suggests that the above generalization may have to be qualified in several respects. Although simplified displays may facilitate transmission of information they do not appear to facilitate transfer or application of what has been learned as well as more realistic displays. Overing and Travers[16] found that students who were taught the principle of refraction of light in water by means of realistic demonstrations were better able to apply the principle in attempting to hit an underwater target than students who were taught by means of simplified line drawings. This study suggests that the primary advantage of realistic displays may be in helping the student to apply what he has learned later on in realistic problem solving situations.

Travers[15] and Van Mondfrans and Travers[17] have also conducted research on the relative efficiency of information transmission through the auditory or visual senses, or some combination of the two senses. In general, their results suggest that instruction involving the visual modality is superior to auditory instruction when the auditory presentation produces some ambiguity in the information transmitted. Thus, the auditory modality was distinctly inferior to all other modality combinations in the learning of a list of nonsense syllables, but no differences between modalities were obtained when meaningful materials were learned. The auditory transmission of a nonsense term produces considerably more ambiguity of interpretation than the auditory transmission of a meaningful word. These results suggest that the use of the visual modality will be particularly effective when the task is to learn new associations such as in learning a foreign language.

Another relevant consideration in interface design is the capacity of the human being for processing information. Travers[15] favors a single channel theory of information processing. According to this view, the human receiver is capable of processing information through only one sensory channel at a time, although the theory postulates a rapid switching mechanism through which the receiver can switch from one channel to another. Accordingly, it is possible to overload the human information processing system by sending messages through multiple sensory channels simultaneously. This condition might result in a loss of information processed by the multi-media CAI interface should be capable of keeping the multiple modalities distinct. This problem is also of concern to the CAI course author who in preparing his graphic and auditory displays must give attention to the information processing limitations of his student.

Another stream of research in psychology has been concerned with the problem of imitation or observational learning. Bandura and Walters[18] have demonstrated that much learning results from the child's observation of the behavior of peers or adult models. Undoubtedly, much classroom learning results from the students' observation and imitation of the behavior of other students and the teacher who serve as effective models. Bandura and Walters have also demonstrated that observational learning occurs as readily from film-mediated models as from live models. These results strongly suggest that an effective instructional environment should provide opportunities for students to observe and imitate the performance of models. To provide adequate opportunities for imitative learning, a CAI interface would have to provide a video tape, closed circuit television, or film projection capability. Provisions for observational learning would seem to be most valuable in science instruction. In learning to use various pieces of scientific apparatus or measuring instruments, the student could watch a video taped demonstration by the teacher and then practice imitating the teacher's behavior. Ideally, such a system should have a playback feature so that students who require more than one demonstration can have the demonstration repeated. Slow motion and stop action would also be of value in breaking down the components of a complex demonstration so that the student can observe the subtleties of the performance.

Another important aspect of the instructional process is that of guidance or prompting of the desired response. The interface must be capable of providing hints or cues to the student when an unusually long response latency indicates that the student is confused, or when the student makes an overt error. Hints may consist of highlighting the correct response in a display by increasing its brightness or size relative to the other words in the display. IBM's *Coursewriter* provides a feedback function which enables an author to provide cues in the form of some of the letters in the correct response. Thus, a student who was unable to name the capital city of New York State could be prompted with the display: A—y. If the student is still unable to produce the correct response after the first prompt, he could be given still more information in the second prompt, such as: A-b-ny. In addition to the guidance provided by prompting, it is also essential that the system provide for the gradual withdrawal of guidance or the "fading of prompts." A prompt should be gradually eliminated over a series of practice trials as the student becomes more certain of the correct response.

Finally, the interface should be capable of providing various forms of positive reinforcement or "rewards" to students as they progress through the course. Reinforcement may often take the form of information to the student concerning his progress through the program. Reinforcement has the effect of sustaining motivation and consequently performance on instructional tasks. Perhaps the most potentially powerful source of reinforcement in CAI is the degree of control which the student can exercise over the course of instruction, the extent to which the student can select his own menu of instruction, and the extent to which the student can query the computer for information. Recent research on problem simulation and economic games programmed for computer presentation (Feurzeig[19] and Wing[20]) suggest that instruction involving conversational interaction and inquiry are highly reinforcing to students. Although these interactive programs place no unusual demands on the stimulus display requirements of the interface, they do extend considerably the requirements for response processing. The interface must be capable of accepting rather lengthy verbal inputs, and the computer must be able to detect key words in a wide variety of verbal responses.

Instructional objectives

Instructional objectives play an important role in determining the interface characteristics required in instruction. It is no great surprise that one of the most successful early CAI projects involved instruction in arithmetic drill (Suppes, Jerman, and Groen[21]). Arithmetic drill provides a relatively delimited class of instructional stimuli and responses. The presentation of arithmetic problems via the interface presents few serious display problems, and the responses are such that little complex response processing is required. As Suppes has demonstrated, elementary arithmetic skills can be easily taught by a relatively simple teletype interface, which provides an important adjunct to regular classroom instruction. As one begins to include other instructional objectives such as diagnosis, remediation, application, transfer, problem solving skill, attitude formation and change, etc., one finds that the interface facilities must be broadened considerably to provide the enriched variety of experiences needed to accomplish these objectives.

SUMMARY

The primary purpose of this paper was to illustrate the effects of different subjects, different students, different learning objectives, and instructional processes on the functional requirements of the student-subject matter interface. Although there is much diversity in the experiences which an instructional environment must provide to students, these experiences also have much in common. The question arises as to whether a single general purpose instructional interface can be developed to teach a wide variety of different subject areas. Glaser, Ramage, and Lipson[1] have addressed themselves to this question. In general, there seems to be some concensus that the next generation up-to-date operational CAI system will have the following capabilities;

(1) Keyboard for response input
(2) Cathode ray tube display with light pen response capability
(3) Video tape or closed circuit television capability built into the CRT unit
(4) Random access image projector with positive address (may be unnecessary if the system provides video tape capability)
(5) Random access audio communication device with positive address.

A CAI system with the above capabilities would be able to provide many of the educational experiences outlined in Table I.

In analyzing elementary mathematics, reading, and science, Glaser, Ramage, and Lipson[1] have outlined some of the major deficiencies of the general purpose interface. These special educational functions may require special purpose interface devices which will be feasible only in experimental CAI systems in the near future. An operational instructional system may have to provide these experiences through regular classroom instruction or special laboratory experiences.

Major deficiencies of a general purpose student-subject matter interface:

(1) Mathematics – Object manipulation to develop basic number concepts; the manipulation of three dimensional geometric figures, line drawings, bisection of angles, drawing perpendiculars, etc. as in geometry. The "Rand Tablet" which is currently operative on some experimental CAI systems provides the graphic response capability required for teaching courses in mathematics, science, and handwriting. The Rand Tablet allows the student to make line drawings, graphs, and diagrams which are simultaneously displayed on a cathode ray tube screen, and evaluated for accuracy by the computer. The Rand Tablet may be operational in future CAI systems.

(2) Reading – Oral response detection for very young children.

(3) Science – The limitations of the general purpose interface in the area of science instruction depend upon the extent to which actual experiences with scientific phenomena can be simulated. Will student learning of scientific concepts be adequate in simulated laboratory experiences, or will direct experience with the actual phenomena be required? Although a number of investigators are presently engaged in the development of simulated science laboratory programs for CAI, these programs have not as yet been evaluated, thus, we must await an answer to the question of the value of simulated experiences in science. One recent doctoral dissertation completed at Penn State has some bearing on the issue of simulated versus actual experience with scientific phenomena. Brosius[22] compared the learning effects of watching films of the anatomy and dissection of the earthworm, crayfish, perch, and frog in biological science with the experience of having the student perform the actual dissections of the animals. Student achievement was measured in terms of achievement of factual information of the anatomy of the animals, skill in the performance of actual dissections, skill in the manipulation of scissors, scalpel, forceps, and probes, and attitude towards science. The filmed demonstrations were as effective as actual dissection on all measures, except the achievement of factual information in which the film method was actually superior to the method involving actual dissection. This study suggests that filmed demonstrations may be just as effective as direct experience in facilitating learning of some concepts in biological science.

Although present technology may be inadequate to accommodate all instructional applications outlined in this paper, it is expected that improvements in the interface will emerge which will closely approximate the requirements of many educational tasks.

The writer's general position is that the interface should "ideally" provide as wide a latitude of stimulus display and response capabilities as possible to accommodate a variety of instructional problems. However, while we wait for the necessary technology to emerge much valuable work can be accomplished with relatively simple interface devices. As we work with first generation equipment we must be especially alert to its limitations in planning the objectives of instruction. Experiences which cannot be adequately provided via CIA must be provided by other "off-line" methods, such as textbooks, workbooks, educational television, laboratories, teacher demonstrations, and maybe even a lecture or two.

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Appendix H.4

Computer-Assisted Instruction: A Simulated Tutorial Approach [1, 2]

Kenneth H. Wodtke

The purpose of my paper today is to describe a research and development project in progress at The Pennsylvania State University. The primary objective of this project is to test the feasibility of simulating the tutorial teaching model in providing college-level instruction under the control of a high-speed electronic computer. My presentation is divided into four parts: a brief nontechnical description of the hardware involved; an example from one of our courses illustrating one possible tutorial strategy; examples of several research problems either presently in progress, or planned for the future which we consider of high priority; and finally, several possible future applications of tutorial computer-assisted instruction (hereafter referred to as CAI) at the college level.

Description of the Penn State CAI System

Since April 1964, faculty members at Penn State have been preparing courses for presentation to students via an International Business Machines 7010 computer system. The courses involved are modern mathematics, management accounting, audiology, and engineering economics, at the college level; and technical physics, mathematics, and spelling at the two-year post-high school technical training level. Courses are being prepared by means of a

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[1] The research described in this report was supported in part by Bureau of Research, U.S. Office of Education under the provisions of Title VII (B) National Defense Education Act of 1958 as amended.

[2] Remarks presented at annual meeting of National Society of College Teachers of Education, February 17-18, 1966, Conrad Hilton Hotel, Chicago, Illinois.

programming language known as Coursewriter developed by IBM computer scientists at the Thomas J. Watson Research Center, Yorktown Heights, New York. The Coursewriter language enables an instructor, with a minimum of special training, to develop a CAI course including questions, problems, assignments, correct answers, incorrect answers, provisions for unanticipated answers, knowledge of results, and branches or alterations in the instructional sequence. By means of additional special codes, the instructor can program the computer to present slides or tape recorded material at the student's terminal, and can request partial-answer processing of student answers. This latter operation permits a student to give answers several words in length and instructs the computer to ignore trivial characters such as commas, periods, spaces, differences in word order, and misspelling if desired. The computer automatically records and stores all student responses, errors, and response times. The instructor can later obtain a print-out and statistical analysis of these data by means of special instruction known as Student Records.

Course material is stored on magnetic discs to which the computer has selective access to any part with an access time of less than one second. A course is presented to students via an IBM 1050 communications system which includes a modified IBM electric typewriter, a random access slide projector, and a tape recorder. Information, questions, or problems can be presented to the student either through typewriter type-out, slides, or tape recordings. In responding to a question or problem, the student simply types his answer on the typewriter and relays it to the central computer by pressing a button. The computer then evaluates the response by comparing it with pre-stored criteria for correct answers, and provides immediate knowledge of results to the student. The student terminals are located on the Penn State campus. Two main computers are in current use, one located on the Penn State campus and the other at Yorktown Heights, New York. Transmission of information between the student and the computer takes place over voice-grade telephone lines by means of teleprocessing.

One example of a CAI tutorial program

Before developing an instructional program based on the tutorial teaching model, it is fair to ask to what extent do we understand the tutorial model. Can we identify the relevant characteristics of such a teaching model? What are the most effective tutorial strategies? The sad fact is that very little is known about the properties of effective tutorial instruction. What little research accomplished on the complex problem of effective instruction has been conducted in classroom or group settings. We frankly admit an eclectic approach in our early course development in CAI at Penn State. However, it is our hope that through experimentation with a variety of strategies, different subject matters, and different students, we can eventually identify the most appropriate instructional strategy for a given student in a given subject matter. Our hypotheses with regard to effective tutorial instruction includes some of the following general characteristics:

1) The tutorial system must be highly flexible in adapting to the abilities, interest, and learning rate of the student.

2) The system must have the capability of evaluating student responses and storing information concerning the nature of these responses for use in making decisions concerning the sequence of instruction.

3) The instructional system must be capable of providing immediate feedback to the student concerning the adequacy of his responses.

4) The system should utilize a multi-media approach to instruction.

5) The system should be capable of providing students with the options to determine their own course of instruction. Students should be required to take some responsibility in deciding how they are to proceed through the course, and when they have reached adequate levels of achievement in the subject matter. The student should not be a passive participant, subject to the whims of the computer program, but should take an active part in instructional decisions.

6) The instructional system should be capable of providing variety in the form of variations in the media of communication, variations in questions, problems, and the kinds of responses a student can make.

Although the above list is not meant to be exhaustive, it does illustrate some of the characteristics we believe to be important in a good tutorial CAI program.

One of our experimental courses which seems to incorporate a number of the characteristics hypothesized to be important in tutorial instruction is Speech Pathology and Audiology developed by Professor Bruce M. Siegenthaler and Mr. Jeffrey Katzer. The first part of this course provides instruction on the anatomy of the ear. A flow chart illustrating the instructional strategy of the course is shown in Figure 1. Those of you who are interested in a live demonstration of this course should note that on-line demonstrations are being given here in Chicago at the Pick-Congress Hotel through noon Saturday, February 19.

Accompanying the flow chart is a key which explains the various sequential steps in the course (see Figure 1). The course consists of three instructional blocks on the outer, middle, and inner ear, and one test block. The course sequence is almost identical in each of the instructional blocks. The student signs on at the terminal by typing the word "start" (box 1) and then progresses to boxes 2 and 3 representing an introduction to the course and an overview of the material on the outer ear. Following the overview, the student comes to box 4 representing the first option of the program and he is asked, "Do you want to skip the outer ear?" If the student answers "yes" he is moved directly to box 10 representing the first step of the middle ear subprogram. If the student chooses to complete instruction on the outer ear at this time, he types "no" and goes to box 5, the instruction on the outer ear. A sample of the dialogue between a student and the computer for the outer ear subprogram is shown in the main body of this report on page Upon completion of instruction on the outer ear, the student encounters another decision in box 6. This time, however; the decision is not a student option, but a decision of the programmer to examine the student's performance on the material just completed. The computer examines the record of errors for the student, and if 33 per cent or more of his responses on the outer ear program were errors, he is branched to remedial material represented by box 7. If the student made fewer than 33 per cent errors on the outer ear program he is sent to box 8 where he is given the option to cover the material on the outer ear a second time. Box 9 is a decision box required by the program to determine whether the student has already been tested on the material covered in the outer ear program.

The sequential decision strategy is essentially the same for the middle and inner ear blocks with one interesting new twist. Before the student is given the option to skip the middle ear block in box 13, the program checks his performance on the previous block again in box 11. If the student's performance was not up to par (fewer than 33 per cent errors) he is not given the option to skip the second major block of instruction, but he is sent directly to box 14 representing instruction on the middle ear. Thus, by means of this strategy, a student is given the option to skip material only when his previous achievement has met satisfactory standards.

Having been sequenced through the three instructional blocks, the student now arrives in the test block at box 26. In box 26, the computer checks its memory to determine whether the student skipped the outer ear block. If the student skipped the outer ear, he goes to box 27 and is tested on the outer ear. Box 28 determines whether his test performance was adequate. If 33 per cent or more of his responses are errors, he is automatically branched back to box 5 for instruction on the outer ear. In such a case, it is assumed that the student misjudged the extent of his knowledge in exercising his original option to skip the material on the outer ear; however, the checks built into the program did not allow him to slip through with insufficient understanding of the material. A similar decision is made for each block of instruction skipped. The student is tested on the material he skipped. When his performance is inadequate, he is branched back for the necessary instruction. After the student has either received instruction or been tested on each block of material, he arrives at block number 38 where he is permitted to type any questions he may have about the course. These questions can later be obtained by the instructor when he requests Student Records for his course.

Obviously there are many different instructional strategies an instructor could have used in programming this material. Although we consider flexibility in instructional strategies an advantage of CAI, the researcher interested in discovering optimal strategies for different subject matters and different students is obviously faced with a terribly complex research problem. We hope to develop through our research program a set of experimental programs which illustrate optimal instructional strategies for different subject matters, and for student groups varying in ability, interest, and past achievement.

Problems for Research in Computer-Assisted Instruction

I will mention briefly two research areas which we regard as high priority areas for research on CAI. First, we are concerned with the effects of computer-assisted instruction on student motivation over long periods of time. Preliminary groups of students have reported high levels of motivation and interest, however, it is not surprising that a new and novel instructional tool produces such positive reactions. How will students react after the novelty wears off?

Related to the question of student motivation is the often reported observation of researchers working with CAI, that students will work at the terminal for very long periods of time without interruption. Other investigators have referred to this apparent phenomenon as the "pin-ball machine" effect. We are presently conducting an investigation to determine the extent of this effect on student attention to the learning task, and on student achievement.

Another question which may be considered under the general heading of student motivation concerns the ways in which simulated tutorial CAI differs from "live" teacher/pupil tutorial instruction. What educational objectives can or cannot be achieved by means of computer-assisted instruction? One study is planned to compare the motivating effects of feedback administered solely by the computer, with feedback administered by the student's own teacher in face-to-face interaction. Preliminary evidence suggests that the effects of the teacher's presence may depend on other student personality variables. Some students report that they like the relative isolation of working at the impersonal terminal, while others say that they miss opportunities for interaction with an instructor.

A second major area of research has to do with the problem of adapting instruction to individual differences in learners. Is it possible to bring a greater number of students to a satisfactory level of achievement by providing the highly individualized instruction which is possible with CAI? One of our projects at Penn State involves experimentation with CAI in technical training programs. This student population typically tends to score somewhat lower in verbal aptitude than the average college student. In spite of wide variations in the verbal abilities of different student groups, our traditional methods of instruction still rely heavily on verbal or written communication. The typical college instructor has high verbal fluency in his area of specialization, and may often make the error of assuming that his students can understand his communications. We propose to develop course samples for CAI which attempt to minimize the language load for students of low verbal ability. Such a course might rely heavily on slides and tape recorded communication. An attempt would be made in preparing the instructional frames to avoid long, complex constructions, and high word difficulty levels. One of the most challenging problems in CAI is the design of instructional programs which adjust instruction to an entire profile of student aptitudes. The medium of instruction should be selected so as to avoid a learner's weaknesses and capitalize on his strengths.

Applications of Computer-Assisted Instruction at the College Level

Although opinions of researchers in the area differ considerably as to the role which CAI should take in the overall educational process, the general consensus at the Penn State Laboratory is that CAI might eventually be used as a supplement to regular classroom instruction. In particular we believe that CAI will find its most useful early applications in providing special forms of instruction to special subgroups of students. For example, college students on academic probation might be given supplementary remedial instruction via CAI in addition to their regular in-class instruction. In a similar manner supplementary enrichment programs might be developed for the highly able student who is frequently forced to mark time in the traditional classroom setting. We are currently conducting an investigation of the achievement of four such groups of college students in CAI. Two groups of students currently on academic probation at Penn State but which differ in level of aptitude, one group scoring high and the other low on the Scholastic Aptitude Test have been located. Two other groups currently on the Dean's list for outstanding academic achievement, but differing in items of high and low aptitude have also been located. The hope is that we can lessen the gap in the achievement of these groups by the systematic individualized instruction provided by CAI.

It is also conceivable that CAI will find useful applications in developing skills for high school drop-outs, retraining the unemployed, providing supplementary remedial instruction in basic skills for the culturally deprived, and in providing in-service training for various professional groups such as teachers, nurses, engineers, etc.

As you can see, those of us working in this area believe that the computer has great potential for accomplishing a variety of educational objectives. In the long run, the extent to which this potential is realized will depend on the ingenuity of the instructional programmer, and the ability of the researcher to provide answers to complex questions concerning the systematic design of instruction.

or whether there are properties unique to computer-assisted instruction which facilitate retention. For example, some writers have talked about what they call the "pin-ball machine" effect in computer-assisted instruction. This phenomenon refers to the apparent tendency of computer-assisted instruction to facilitate high levels of attention to the instructional materials for long periods of time. These effects may be due to the novelty of the instructional method and may wear off after some time. However, the high attention to the task may be longlasting resulting from certain properties of tutorial interaction which students find highly reinforcing. Unfortunately, the tutorial process has not been extensively studied in educational research, however; the hypothesis that tutorial interaction facilitates attention and student motivation resulting in improved retention would seem tenable.

An alternative hypothesis is that the rate of forgetting depends almost entirely on limits in the information storage capacities of the learner, and not to any great extent on the nature of instructional stimulus or its mode of presentation. Thus, one might predict that raising the amount learned in the second treatment group of Figure 4 by providing additional instructional time would increase the rate of forgetting so that the performance curve would become more like that of group one. The old maxim "The more you have learned, the more you can forget" may operate here. However, most experimental research suggests that phenomena such as rate of forgetting and transfer depend on factors both in the learner's storage capacity and in the learning task. Questions such as this can only be answered through research. The investigation of instructional methods which may produce decreases in the rate of forgetting, in addition to producing increases in the overall level of performance, should be given much more attention by educational research workers.

Some procedures for controlling the amount learned in the study of retention

Direct experimental control of the amount learned. A number of procedures may be appropriate to control the effects of the amount learned while examining retention effects. Underwood (1964) has suggested a two-stage experimental procedure in which treatment groups are brought to the same level of learning and then tested for retention after some time interval. Although this procedure seems feasible in experiments using laboratory tasks, it is often impossible to bring students to a common criterion performance on complex educational tasks. Furthermore, bringing subjects to a common criterion means allowing some students more trials or more time at the task, thus, confounding the effects of the treatment with time spent at the task.

Repeated measures analysis. The analysis of retention data can be viewed as a problem of comparing the rates of forgetting curves. A repeated measures analysis provides evidence concerning the overall effects of the experimental treatments, and in addition, provides tests for the differences in slopes of the forgetting curves obtained from the successive posttest measures. Excellent descriptions of repeated measures designs have been given elsewhere (Winer, 1962; Grant, 1965). Only a brief description of the application of the design and analysis to the study of retention effects will be given here.

The repeated measures design which seems most appropriate for the study of differential rates of forgetting is a two-way factorial design with repeated measures on one experimental factor (see Figure 5). Factor A would consist of two or more experimental treatment comparisons. Factor B, the repeated measures factor, would consist of two or more measures of retention over time. A statistically significant overall main effect for Factor A would indicate that one instructional treatment was generally superior to another. A statistically significant A X B treatment by retention measures interaction would indicate that the slopes of the retention curves in the treatment groups differed. In addition, when the number of retention measures is greater than two, a trend analysis can be performed to determine the shape of the forgetting curves. Grant (1956) has provided an excellent discussion of the application of trend analysis in learning experiments involving repeated measurements.

The repeated measures design used for studies of retention may or may not include a pretest measure of the students' knowledge of the subject matter to be taught prior to experimental instruction. The decision to use a pretest will depend on the extent to which the subjects are familiar with the experimental learning material. Winer(1962) describes a repeated measures analysis of covariance design which would be appropriate for a study in which a pretest was administered in addition to repeated measures on one or more experimental factors. In this way it would be possible to control the relationship between prior knowledge, the degree of learning, and the rate of forgetting.

An assumption underlying the use of the repeated measures analysis of variance is that of homogeneity of variance and covariance across all levels of the repeated measure. Successive measures of performance over time frequently produce a variance-covariance matrix of the simplex pattern in which the variance decreases in magnitude from the initial to final measurements, and in which the covariance of adjacent measures is higher than the covariance of measures widely separated in time. Where such a variance-covariance matrix is observed, or for any case of heterogeneity of variance-covariance, Cole and Grizzle (1965) have developed an appropriate multivariate analysis of variance for repeated measurements which does not depend on the usual assumptions.

The analysis provides tests for all the main effects, interactions, and trend components provided in the usual repeated measurements procedure.

Change scores. The problem of studying retention of forgetting effects in educational experiments is a special case of the more general problem of measuring behavior change. An investigator interested in retention is concerned with the differential "loss" of subject matter competency which can be attributable to different experimental treatments. In recognizing the need to control the amount learned by treatment groups, some investigators have resorted to simple difference scores (e. g., posttest 1 minus posttest 2) to measure loss over time. However, simple difference scores present many difficulties and generally do not provide an adequate measure of change. The disadvantages of simple difference scores have been thoroughly discussed elsewhere (Bereiter, 1963; Thorndike, 1965). In general, simple difference scores are highly susceptible to artifacts due to regression effects, tend to be much less reliable than initial or final status scores, and are likely to be highly affected by less than ideal metric properties such as the lack of an equal interval scale. In view of these difficulties, and in the light of more recent developments in the measurement of change (Mayo and DuBois, 1963; Lord, 1963), simple difference scores would not be recommended as a measure of retention or loss due to forgetting.

Newer developments in the measurement of change seem to offer promise as measures of gain or loss due to learning or forgetting. Mayo and DuBois (1963) recommend the use of residual scores in the study of change. The use of residual scores helps solve one of the problems associated with simple difference scores. Simple difference scores have been found to correlate negatively with initial status scores in a number of investigations. As Lord (1963) points out, this negative relationship is sometimes due to a real relationship between gain and initial status (e. g., heavy people are more likely to get lighter; lighter people are more likely to gain weight), or sometimes due to an artifact of errors of measurement. Often an investigator is not interested in the relationship between initial status and gain but between gain and some other variable with initial status held constant. This is precisely the problem in a study of retention where one wants to relate the degree of loss to an experimental treatment with the amount learned during the treatment period held constant. Mayo and DuBois (1963) recommend the use of residual posttest scores obtained by partialing out the effects of initial status. The procedure is equivalent to a part-correlation in which residual posttest scores are correlated with other variables of interest. When a residual gain score serves as the dependent variable in a comparison of experimental treatments the procedure is equivalent to an analysis of covariance. Some slight variations in the two procedures might occur as a result of using different regressions for obtaining the residual scores. The use of analysis of covariance or residual scores to measure loss over time seem to have application in studies of retention. However, there are some cautions in the use of these procedures to be discussed below under the section on analysis of covariance.

The analysis of covariance. One of the most widely used analyses in studies of change in educational experiments has been the analysis of covariance. Surprisingly, however, the analysis of covariance has not been widely used in studies of retention over time. As mentioned above, the analysis of covariance applied in a study of change is almost identical to the use of residual gain scores. In the retention experiment, the analysis of covariance provides a method for controlling the amount learned statistically.

The application of the analysis of covariance to the study of retention involves the use of the immediate posttest measure as the covariate and the delayed posttest as a dependent variable. A test for significance of differences on the delayed test with differences on the immediate test held constant can be obtained. This application of the analysis of covariance differs from the usual application in that the covariate is administered after the experimental treatment and may be affected by the treatment. In the usual analysis of covariance the covariate is administered prior to experimental treatment. The application of the analysis of covariance in experiments in which the covariate is affected by the experimental treatment has been discussed in papers by Gourlay (1953), Cochran (1957), and Smith (1957).

The writer has been able to find only a few examples of this use of the analysis of covariance in the literature. In an experiment by Prokasy, Grant, and Myers (1958), a two-way classification design was employed to test the effects of unconditioned stimulus (USC) intensity and intertrial interval on the extent of eyelid conditioning. Three measures of eyelid conditioning were obtained for acquisition on day 1, for acquisition on day 2, and for extinction. In the analysis of covariance, day 1 acquisition scores were used as the covariate for testing the day 2 measures, and the day 1 and 2 combined acquisition scores were used as the covariate for testing the extinction scores. Only the effects due to USC intensity held up in the covariance analysis. The intertrial interval and interaction effects were nonsignificant following the analysis of covariance adjustment indicating that the effects of intertrail interval appear to be concentrated during the early acquisition trials.

In a doctoral dissertation recently completed at Penn State, Dwyer (1965) compared the effects on student learning of several varieties of visual illustrations as a supplement to verbal instruction. The treatments consisted of varying in their degree of realistic detail. The research design employed was a single factor, pre-posttest design, with a second posttest administered as a ten-day retention test. The immediate retention test data were analyzed by means of the analysis of covariance with the pretest as the covariate. This analysis supported the conclusion that simpler line drawings and stick figures produced achievement superior to that of slides containing more realistic details. Table 1 shows the analysis of the delayed retention test data. The left-hand part of the table shows the simple analysis of variance with the delayed retention measure as the dependent variable. The right-hand part of the table shows an analysis of covariance on the delayed retention measure with the immediate retention measure serving as the covariate. A multiple analysis of covariance using both the pretest and the immediate retention measures as covariates could also have been used here. The results show a statistically significant F-ratio for the analysis of variance dropping to nonsignificance in the analysis of covariance which adjusts for group differences in the amount learned as measured by the immediate posttest. Table 2 shows the adjusted means on the immediate and delayed retention measures, and the unadjusted delayed retention test means for the four treatment groups. The similarity of the delayed posttest means when adjusted for the effects of the treatments on achievement measured immediately following instruction, indicates that the treatments did not appear to differentially, effect the degree of loss due to forgetting.

Although the analysis of covariance provides a method for controlling statistically the amount learned in studies of retention, the procedure is not free from ambiguity of interpretation. For example, Lord (1965) described a paradox in which the use of observed gains and residual gains resulted in contradictory conclusions concerning the comparative growth of two groups on some variable. This paradox results when the groups to be compared differ on the initial status measure. The analysis of covariance or residual score method anticipates regression towards the mean on the second testing. If such movement towards the mean does not occur (e. g., if the groups show identical observed changes from the first to second testings), the adjusted mean difference on the second measure following analysis of covariance will show a superiority of gain for the initially high group. The initially high group is said to have shown more growth than expected in the face of the tendency of the mean of that group to decrease due to regression, while the initially low group showed less than the expected amount of growth. Thus, while the observed change scores would indicate that the groups did not differ in the amount of change, the analysis of covariance would support the conclusion that the initially high group exhibited more gain than the initially low group.

Multivariate analysis. The analysis of covariance procedure described above is closely related to a number of recently developed analytical methods designed for the analysis of experiments involving several correlated dependent variables. The problem of correlated learning and retention measures is a special case of the more general problem of correlated dependent variables. Correlated dependent variables may also arise from the use of measures such as reading achievement, arithmetic achievement, related achievement or aptitude subtests, and related personality measures in the same experiment. What investigator has not intuitively recognized the redundancy and ambiguity involved in computing ten or twenty "separate" analyses of variance on as many dependent variables which correlate with one another of the order .50? Some investigators, in recognizing the problem of correlated dependent variables, have resorted to factor analysis to reduce the number and redundancy of the variables prior to testing hypotheses concerning the effects of experimental treatments. Recent developments in multivariate methods represent a further advance in the analysis of correlated dependent variables (Bock, 1963; Roy, 1958; Cole and Grizzle, 1965). In addition, practical applicability of these methods has been greatly enhanced by the development of computer programs to carry out the analyses.

One multivariate technique seems particularly appropriate to the analysis of the effects of experimental treatments on retention measures with the amount learned held constant. Roy (1958) has developed a step-down multivariate analysis (also described by Bock, 1963) for use with a series of correlated dependent variables which can be arranged in order on *a priori* grounds. The logical ordering of variables in a study of learning and retention would seem to follow the order in which the measures were obtained following experimental treatment. Roy describes the methods as follows:

> The hypothesis concerning the multivariate distribution is then decomposed into a number of hypotheses--the first hypothesis concerning the marginal univariate distribution of the first variate, the second hypothesis concerning the conditional univariate distribution of the second variate given the first variate, the third hypothesis concerning the conditional univariate distribution of the third variable given the first two variates, and so on. (Roy, 1958, p. 1177)

Applied in an experiment in which a number of successive retention measures are obtained, the step-down analysis should provide an analysis very similar to that used in the Prokasy, Grant, and Myers experiment described above. The first test concerns the effects of the experimental treatment on the immediate posttest (or measure of the amount learned); the second test concerns the effects of the treatment on the first delayed retention measure, with the effects of the immediate posttest partialed out; the third test concerns the effects of the treatment on the second delayed retention measure with the combined effects of the immediate posttest and the first delayed retention test partialed out, etc. The statistical significance of the second and third tests, and any successive tests, would indicate that the experimental treatments had differential effects on long term retention which were independent of the amount learned. A computer program has been developed for this analysis at the Psychometric Laboratory of the University of North Carolina (see Bock, 1963).

Separate Groups Design

One of the difficulties with the successive posttest design discussed thus far is that the act of taking a pretest, or successive posttests may effect to some extent, a subject's recall of the subject matter. Underwood (1957) has shown that a substantial amount of the forgetting obtained in verbal learning experiments employing repeated measures designs results from the proactive interference of previously learned materials. If the effects of retesting were constant across groups the treatment comparisons would not be confounded, however, the absolute amount of forgetting in each group would not be free from the effects of repeated testing. If the effects of testing interacted with the treatment effect, the retention comparison would be confounded with this interaction.

One design which has been used in studies of communication and persuasion (Hovland, Janis, and Kelley, 1953) and has been discussed by Campbell and Stanley (1963), avoids the use of repeated posttests. This design employs separate randomized groups in a two-way factorial set-up in which one factor consists of the experimental treatments, and the other consists of a different time delay in the administration of the posttest. A treatment by time-delay interaction indicates the presence of differential long-term retention effects.

One recent application of this design can be found in a study by Williams and Levy (1964). Campbell and Stanley (1963) point out that, although this design is comparatively sound, it suffers from the potential invalidity of effects due to an interaction between the treatment and the events occurring during the retention interval.

Some problems associated with existing methods for the study of retention

To some extent, each of the methods for studying retention discussed above suffer two major shortcomings common to much experimentation in psychology and education: the lack of equal interval scales for measuring learning and retention, and the effects of measurement error in the dependent variable. Measures of change such as those involved in studies of retention over time are likely to be particularly susceptible to the effects of inequality of scale intervals. Thorndike (1965) has shown that results with difference scores are likely to be particularly distorted by inequality of scale increments of the initial and final status measures. Unequal scale units are likely to produce variations in difference scores (or in forgetting "curves" based on two posttest measures) which are not attributable to treatment effects but to artifacts of the scales. The possibility of such effects argues for the use of several successive posttest measures to establish more reliable trends in the forgetting curves.

Ghiselli (1964) argues that variations in the equality of scale units are probably distributed at random throughout the range of the scale in the case of most achievement tests. If this was the case, it would be highly improbable that random differences in the equality of intervals would be mistaken for true differences in forgetting. However, where ceiling and floor effects exist, the inequality of intervals is not randomly distributed throughout the scale and retention data in the form of change scores or curve slopes will most likely be highly distorted.

As for the problem of the low reliability of measures, it is well known that measures of behavior change are typically much less reliable than single status scores. Lord (1963) has developed a technique for estimating true change for individuals given the reliability of the pre- and posttest measures. Essentially a special application of the correction for attenuation, Lord's procedure can be used to obtain a partial correlation between estimated true gain and a third variable of interest with true initial status held constant. Although Lord's procedure is probably not generalizable to the problem of group comparisons, it would be highly desirable to have an estimate of the proportion of error variance attributable to measurement error for the dependent variable in the typical analysis of variance design. The within variance of an analysis of variance design has traditionally been said to consist of two *scources* of error; experimental error and measurement error. An appropriate analytical method should include a procedure for reducing the within groups variance by an amount attributable to errors or measurement. The remaining variance would constitute *experimental* error variance. Such a procedure would provide far more precise tests of hypotheses concerning the effects of experimental treatments on measured change. The analysis would provide an *estimation* of what the results of an experiment would have been had the measures of the dependent variable (e.g., change) been perfectly reliable. If an estimate of the reliability of a dependent variable measure is available in an experiment, there seems to be no logical reason for not utilizing this information when performing hypothesis tests of the effects of experimental treatments on that variable. Measurement errors simply increase the within variance and decreases the sensitivity of the experiment to true effects. One of the problems which still remains to be solved in experimentation on the determinants of behavior change is the development of an analysis which takes into account the presence of errors of measurement and removes this component of variance from the estimate of experimental error.

Summary

The purpose of the present paper was to point out certain difficulties in the interpretation of retention data in educational experiments, and to suggest several established experimental designs which seem appropriate for the study of retention effects. The essential problem in the study of the effects of experimental treatments on retention over time is that such effects are likely to be confounded with the effects of the treatments on the degree of learning. This confounding results from the fact that measures of learning or immediate retention, and measures of delayed retention are usually highly positively correlated. Several research designs are considered some of which provide tests for differences in rate of forgetting, and others which provide tests for differences on delayed retention measures with immediate retention measures held constant. A focus in educational research on variables on instruction which facilitate long-term effects such as retention and transfer is advocated.

Footnotes

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[2] For an excellent discussion of this problem in the context of experiments on verbal learning see Underwood, B. J., Degree of learning and the measurement of forgetting. Journal of Verbal Learning and Verbal Behavior, 3: 112-129; April, 1964.

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	X_o		X_1		X_2
Experimental Group 1	Pretest	Treatment 1	Posttest 1	Time Interval	Posttest 2
Experimental Group 2	Pretest	Treatment 2	Posttest 1	Time Interval	Posttest 2

Figure 1. Illustration of a design frequently used to study the effects of experimental treatments on retention.

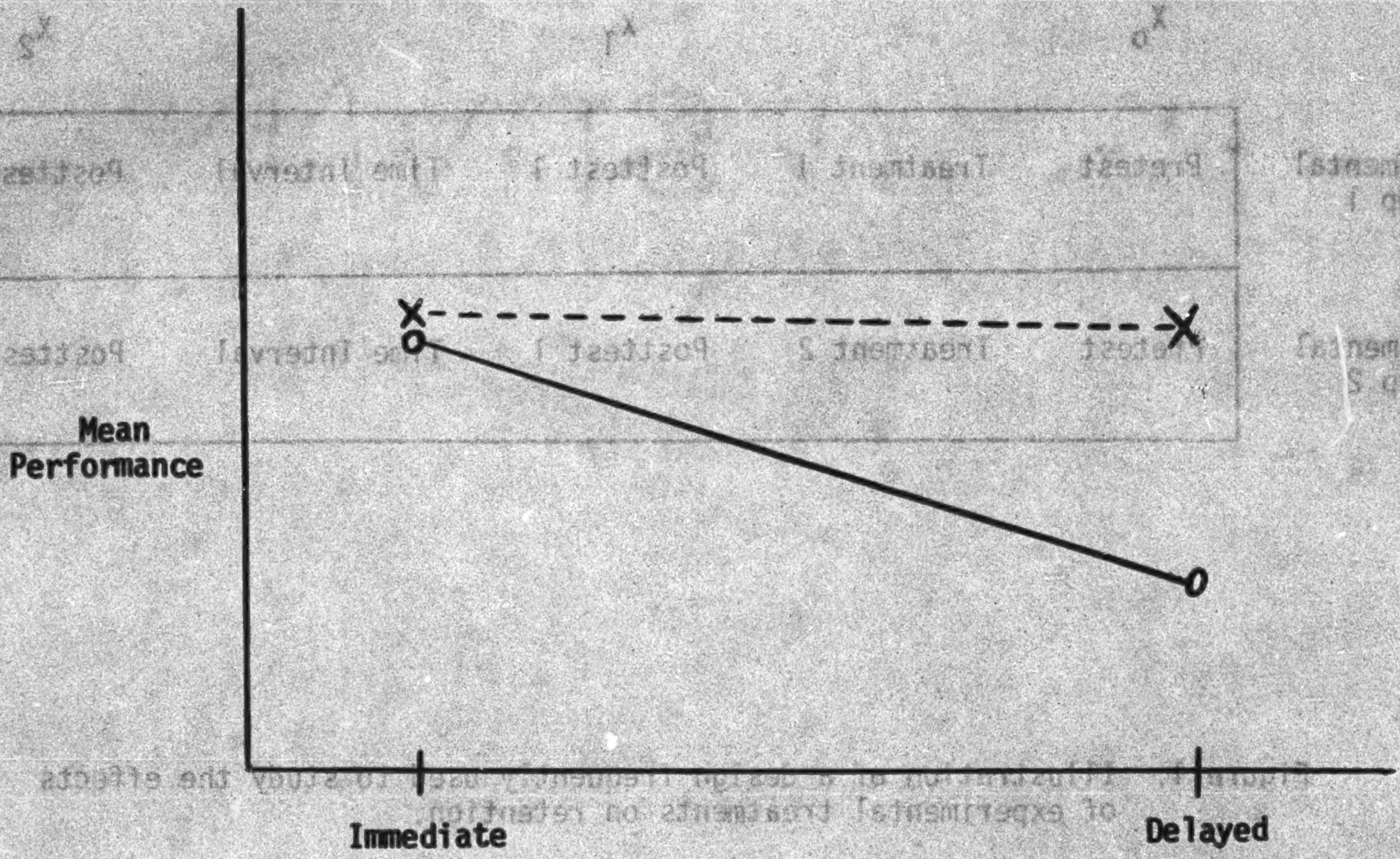

Figure 2. Results of hypothetical experiment involving retention data.

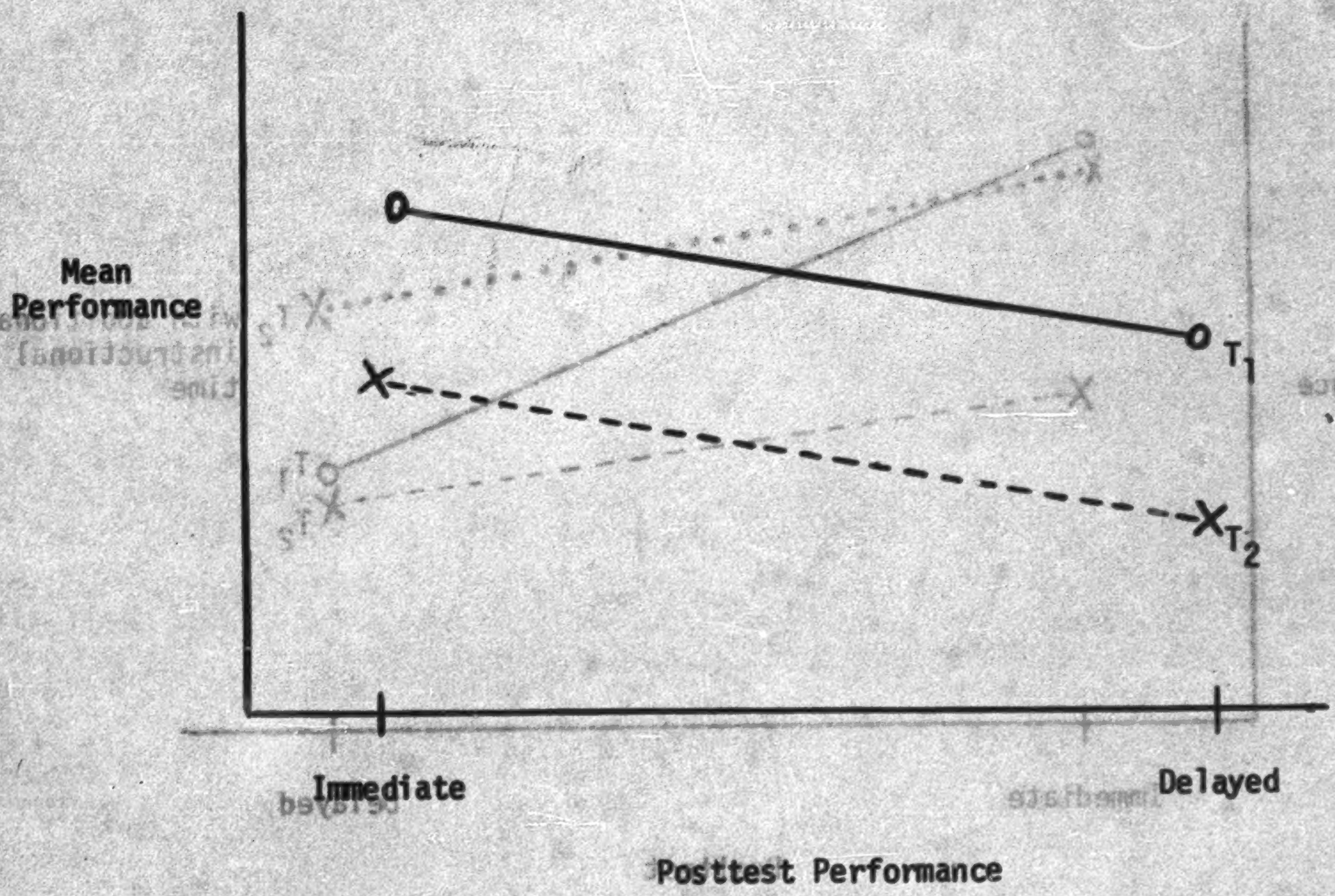

Figure 3. Results of hypothetical experiment involving retention data.

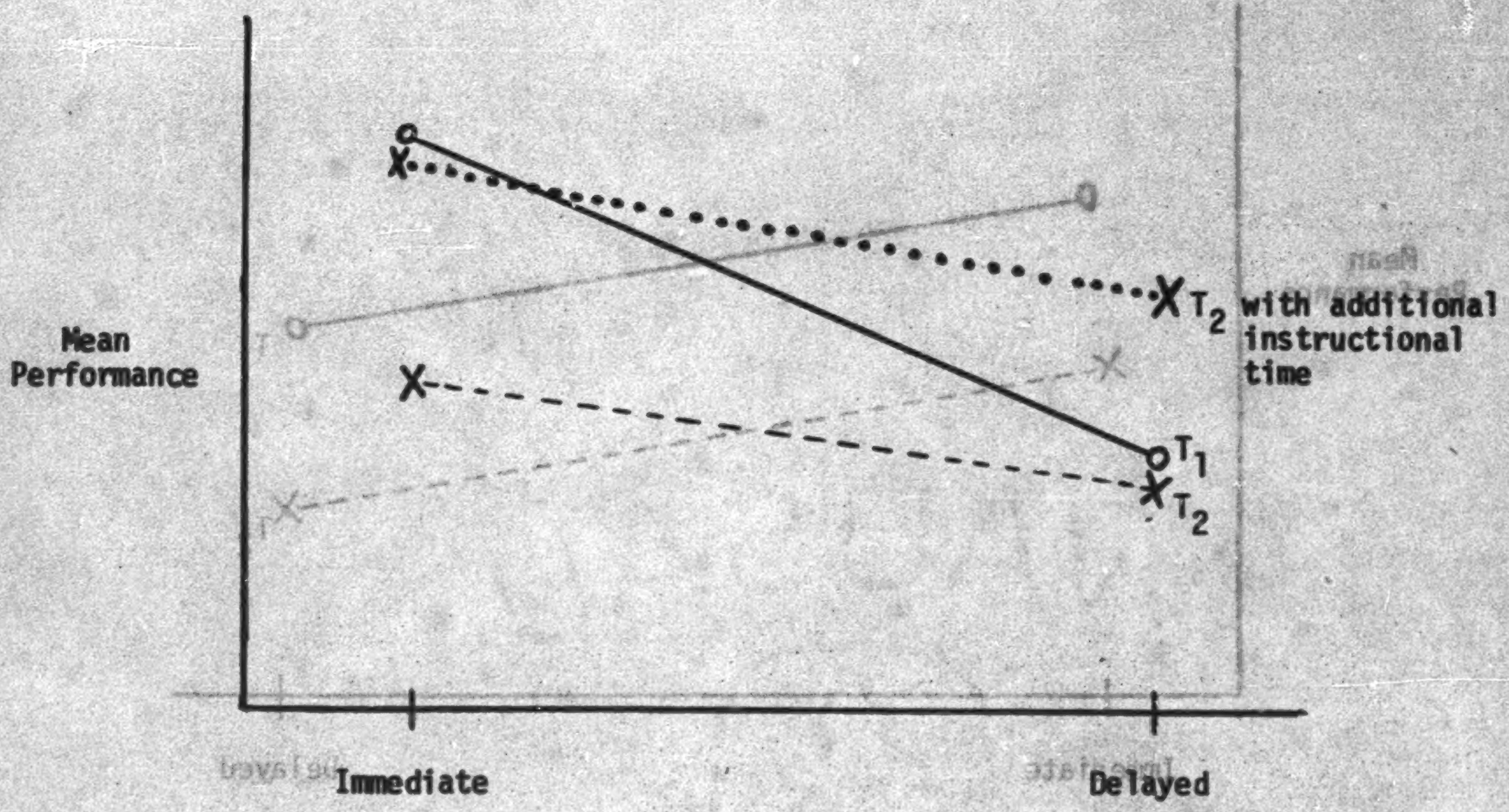

Figure 4. Results of hypothetical experiment involving retention data.

Figure 5

Repeated Measures Design for the Study of Differential Retention Effects

		Factor B (Retention Measure)	
		R_1	R_2---------R_n
Factor A	Treatment$_1$	Group$_1$	Group$_1$------Group$_1$
	Treatment$_2$	Group$_2$	Group$_2$------Group$_2$
	Treatment$_K$	Group$_K$	Group$_K$------Group$_K$

Table 1* Analysis of Variance and Covariance on the Delayed Total Criterion Retention Test Scores for the Four Treatment Groups.

Variance	Original Analysis					Adjusted Analysis				
	D.F.	Sum of Squares	Mean Square	F	p-value	D.F.	Sum of Squares	Mean Square	F	p-value
Among Groups	3	4,691	1,563.67	7.10**	.01	3	222.80	74.27	1.38	n.s.
Within Groups	78	17,173	220.17			77	4,130.83	53.64		
Total	81	21,864				80	4,353.60			

**Significant at the .01-level

*From Dwyer, F. M., Jr. An experimental evaluation of the relative effectiveness of selected visual illustrations in teaching science concepts to college freshmen. Unpublished Doctoral Dissertation, Pennsylvania State University, 1965.

Table 2

Adjusted and Unadjusted Treatment Means on the Immediate and Delayed Retention Tests*

Treatment	n	Mean Immediate Retention Score (Adjusted)	Mean Delayed Retention Score (Unadjusted)	Mean Delayed Retention Score (Adjusted)
Oral Presentation (Group I)	20	41.00	46.45	53.56
Linear Presentation (Group II)	23	56.09	61.48	54.80
Drawing Presentation (Group III)	24	55.42	56.67	50.60
Photographic Presentation (Group IV)	15	37.33	41.87	52.33

*From Dwyer, F. M. Jr. An experimental evaluation of the relative effectiveness of selected visual illustrations in teaching science concepts to college freshmen. Unpublished Doctoral Dissertation, Pennsylvania State University, 1965.

Appendix H.7

SOME PRELIMINARY RESULTS ON THE REACTIONS OF STUDENTS TO COMPUTER-ASSISTED INSTRUCTION

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The purpose of the present paper is threefold: to describe briefly the characteristics of a computer-assisted instructional system (hereafter referred to as CAI) in operation at Pennsylvania State University, to report preliminary evidence on the initial reactions of a group of 47 students to CAI, and to indicate several questions for future research raised by these initial student reactions.

Description of the CAI System

Faculty members are preparing four courses for presentation to students via an IBM 1410 computer: modern mathematics, cost accounting, audiology, and engineering economics. Courses are prepared by means of an author language known as Coursewriter developed by IBM computer scientists at the T. J. Watson Research Center, Yorktown Heights, N.Y. The Coursewriter language enables an author, with a minimum of special training, to include questions, problems, assignments, correct answers, incorrect answers, provisions for unanticipated answers, knowledge of results, and branches or alterations in sequence in his course. In addition, an author can employ a function called Student Records which will record and accumulate in storage all student errors and response times. Additional operations can call for the presentation of a slide or taped material at the student's terminal, and for partial answer processing of student answers. This latter operation permits student answers several words in length and instructs the computer to ignore trivial characters such as commas, periods, spaces, differences in word order, and misspelling if desired.

The course is stored on a magnetic disc to which the computer has selective access to any part with an access time of less than one second. The course is presented to students via an IBM 1050 communications system which contains a random-access slide projector and a tape-recorder attachment. The teaching terminal consists of a modified IBM electric typewriter through which the computer types out course material to a student seated at the terminal. In answering a question or problem, the student simply types his answer at the terminal and relays it to the central computer, which in turn provides knowledge of results to the student. The teaching terminal is located on the Penn. State campus, while the main computer is located at Yorktown Heights, N.Y. Transmission of information between the student and the computer takes place over long distance telephone lines by means of teleprocessing.

Reactions of Students to CAI

Forty-seven students have completed some computer-assisted instruction at Penn. State. Of these, 18 have worked in audiology, 21 in cost accounting, 7 in modern mathematics, and 1 in engineering economics. The results fall into three general categories: (a) mean student self-reports of reactions to CAI, (b) selected correlations among a number of student variables and performance in CAI, and (c) impressions as obtained from guiding students through the courses and from informal interviews with students following their experience with CAI. The results should be regarded as tentative and suggestive of hypotheses for further study under highly controlled conditions. The 47 students were the first pilot group to test the CAI courses; they are not a random sample of college students, nor were they assigned at random to the four courses. Frequently, the students were used to help "debug" the courses, and problems were encountered by the student which would not ordinarily occur with a finished course. In addition, these early results are primarily of a correlational and descriptive nature, with the accompanying difficulties of determining the nature and direction of causation. In spite of the above qualifications, there appear to be some meaningful differences among the scales of the student-reaction inventory and some clusters of intercorrelations which "make sense" and support our subjective impressions.

Following the first session of CAI each student completed a Student Reaction Inventory consisting of a number of scales modeled after the Semantic Differential (Osgood et al., 1957). The extremes of each scale are defined by pairs of bipolar adjectives such as good-bad, dull-interesting, tense-relaxed, etc. Thirty-one students completed the reaction inventory (the first 16 students were taught prior to the development of this device).

A profile of the mean ratings on 12 attitude scales was constructed for the total group, and separately for each course. An examination of the high points on the profile of student attitudes towards CAI indicates that students found the experience highly interesting, good, fair, valuable, and active, and that the students reported being able to give the machine more attention than a traditional classroom lecture.

That students react favorably to a new and novel instructional technique such as CAI is reassuring but not particularly surprising. The low points in the profile of student reactions may be of greater importance in pointing the way to improvements in the instructional system and toward new instructional strategies. The three lowest points in the profile indicated that the students reported being relatively tense as opposed to relaxed, finding the program inflexible, and missing opportunities for discussion. Fifty-four per cent of the sample reported being "slightly tense" during the first session of CAI. We have no decisive data at present to indicate whether the reported tension had a positive or negative effect on student achievement and retention. It appears that some students are simply highly motivated to do well in the course, while others get flustered by the machinery.

The student self-reports seem to agree with informal observations of students working at the terminal. Some students seem "machine shy" during the first hour of instruction, and comments such as "I'm afraid I'll do something wrong" or "I'm afraid I'll break the machine" are quite common. Students usually report being more relaxed at the end of the first session of instruction. These observations have led us to consider the need for longer warm-ups or an introduction to CAI which would prepare the student for instruction.

The report of program inflexibility seems to have resulted from the requirements of an earlier CAI system which required a perfect correct-answer match. Answers which were essentially correct, but differed in some trivial character (frequently unnoticed by the student, such as spaces, upshifts, and downshifts, etc.) were judged incorrect by the machine. A computer which will not ignore trivial characters such as commas, periods, spaces, etc. and correctly evaluate a correct answer is judged inflexible by students. These reports emphasize the need for partial-answer processing in CAI systems.

Students also rated the machinery as quite "fast." This reaction raises the question of the rapidity of CAI. CAI frequently appears to qualify as an instance of massed practice. Although the system is in theory student paced, the immediate presentation of the next question following a correct answer paces the student. A study is presently underway to investigate the effects of student-controlled pauses in the presentation of the course. Unfilled delays might provide time for students to process information and to rehearse their responses, and might be especially valuable following the correction of an error.

Correlations among Selected Student Variables, Reactions to CAI, and CAI-Performance Variables

A missing-data correlational analysis of a matrix of variables including student errors, rate of performance, SAT scores, cumulative grade-point average, Bernreuter personality scales administered to all entering freshmen at Penn. State, student reactions to CAI, etc., was computed. The analysis was performed for the total group, and separately for students in audiology and cost accounting. Keeping in mind the difficulties of a posteriori "data snooping," the writers examined the matrix in an attempt to find nonchance, meaningful clusters of correlation coefficients. The results reported below are those which in the writers' judgment seemed to tie together.

Although there are probably few individuals working in CAI who question the educational advantages of partial-answer processing, some of the present results make quite clear the problem of the nonmatched correct answer from the student's viewpoint. (The present data were obtained prior to the availability of partial-answer processing.) In scoring the student's record for errors, it was necessary to distinguish between legitimate content errors and what were called correct answers entered in wrong form which were regarded as incorrect by the computer. The mean per cent content errors, based on the student's total number of responses for all courses was 20%, while the mean per cent correct answers entered in wrong form was 17%. The correlations between the two types of errors were positive and significant at less than the .001 level for the total group and within each course. This correlation reflects the fact that the student types in the correct answer in wrong form, tries the same answer once or twice more just for good measure, and then discards his original correct answer for an incorrect response, thus, making a content error. Some persistent students may type in their original correct answer again and again. When number of questions was used as the base for computing the percentage of errors, several students exceeded 100%. An additional problem is that these persistent students may be the most self-sufficient students, and the system is negatively reinforcing self-sufficient behaviors. The Bernreuter Stability and Self-Sufficiency scales correlated significantly and positively with the percentage of correct answers entered in wrong form (.43 and .56, respectively). The manual for the Bernreuter describes the measure of self-sufficiency as follows: "Persons scoring high on this scale prefer to be alone, rarely ask for sympathy or encouragement, and tend to ignore the advice of others. Those scoring low dislike solitude and often seek advice and encouragement."

Although the problem of correct answers in wrong form can be minimized by specific instructions to students at the beginning of a course or by inserting additional correct answers, some wrong-form errors result from typing habits and poor punctuation. A correlation of .35 (p=.05) between the number of lines of program covered by a student per hour and a Punctuation subtest score on the Penn. State entrance examination was obtained. Furthermore, a negative correlation of −.26 approaching significance between Punctuation scores and percentage of wrong-form errors was also obtained.

The correlations in Table 1 (shown for the total group and also for the cost accounting group in parentheses) generally indicate that students having lower cumulative grade points and scoring lower on the entrance battery tended to rate the course and machine as fast. The correlations of several subtests from the Penn. State entrance battery with percentage of content errors are suggestive of a similar negative relationship, although they are less consistent. These data are indicative of the importance of the speed factor, and suggest that courses employing optional delays, optional review, and optional remedial work would be beneficial for some students.

Table 1

Correlations Among Some Cognitive Measures, Reactions to the Speed of CAI, and Percentage of Content Errors

N = 21

	Penn. State Entrance Exam Subtests (Moore-Caster)					
	C.G.P.A.	Vocab.	Para. Reading	Spelling	Punc.	Total
Rating:						
Course Fast	−.15 (−.50)**	−.27 (−.51)**	−.33 (−.29)	−.14 (−.43)*	−.08 (−.12)	−.30 (−.37)
Machine Fast	−.35* (−.69)**	−.37* (−.44)*	−.37* (−.49)*	−.31 (−.46)*	−.11 (−.24)	−.32 (−.38)
Per Cent Content Errors	.13 (−.12)	−.20 (−.36)	−.11 (−.27)	.06 (−.48)**	.08 (−.30)	−.26 (−.45)*

* p < .10.

** p < .05.

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